TM 10-580

WAR DEPARTMENT

U. S. Dept. of Army

TECHNICAL MANUAL

# AUTOMOTIVE ELECTRICITY

# TECHNICAL MANUAL

## AUTOMOTIVE ELECTRICITY

CHANGES No. 1 } WAR DEPARTMENT, WASHINGTON, March 21, 1942.

TM 10-580, January 29, 1941, is changed as follows:

**38. Spark control.**

* * * * * * *

*e. Vacuum.*—When the throttle is only partly open, the engine cylinders take in only part of the full charge during each intake stroke. As a result, the compression pressures during part-throttle operation are low, which causes slow burning of the charge. For improved performance and fuel economy during such operation, it is desirable to have a spark advance greater than that obtainable with the centrifugal mechanism alone, which reacts only to engine speed. To secure the additional advance, vacuum in the intake manifold and carburetor (which varies with throttle opening) is used. The combined action of centrifugal and vacuum units gives greater efficiency by meeting all conditions of engine operation.

* * * * * * *

[A. G. 062.11 (12-20-41).] (C. 1, Mar. 21, 1942.)

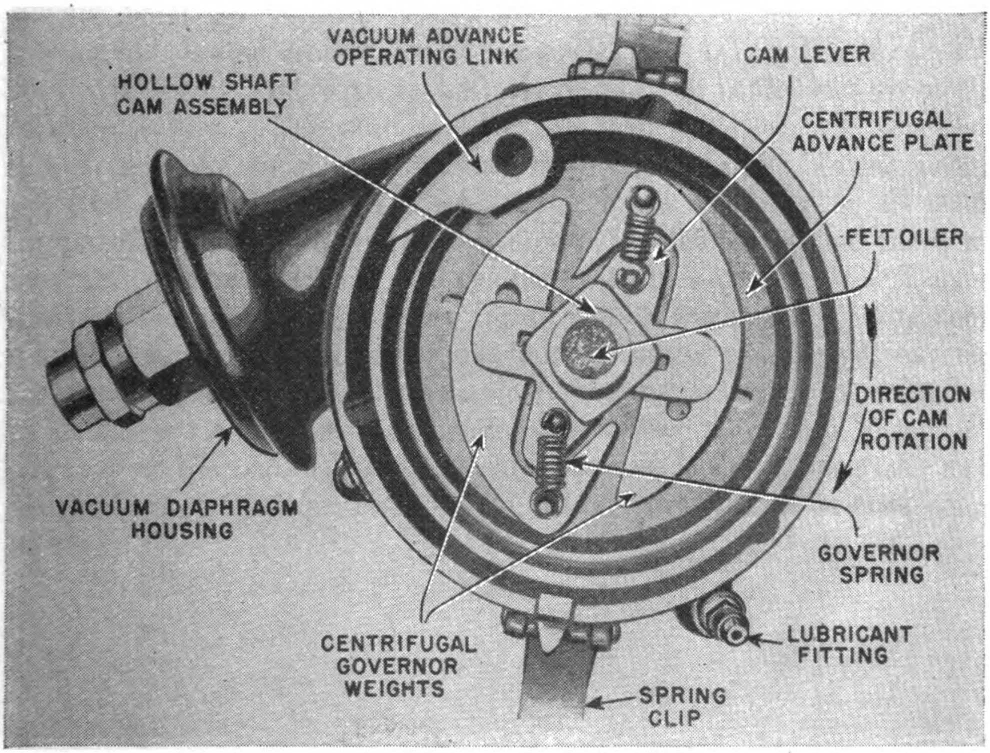


FIGURE 55.—Automatic spark advance mechanism operated by a centrifugal governor (breaker plate removed).

[A. G. 062.11 (12-20-41).] (C. 1, Mar. 21, 1942.)

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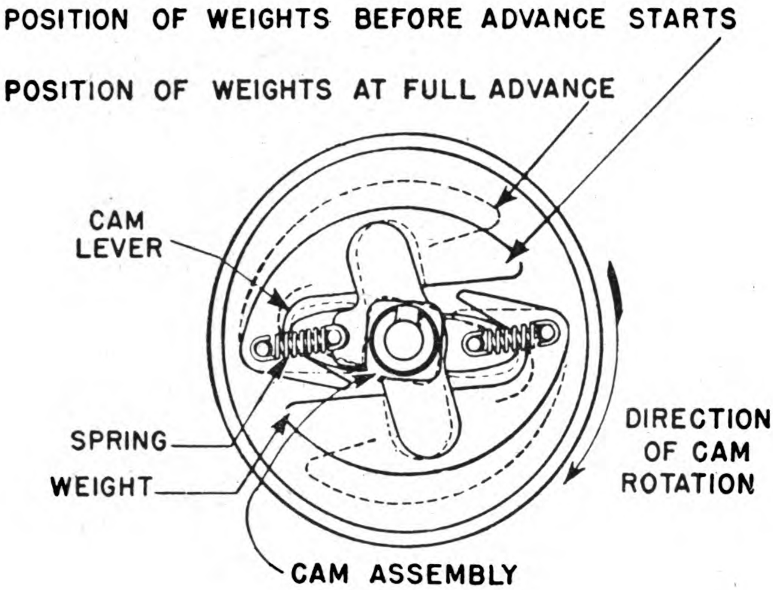


FIGURE 56.—Action of centrifugal weights.

[A. G. 062.11 (12-20-41).] (C. 1, Mar. 21, 1942.)

**79. Switches.**

* * * * * * *

*c. Blackout lamp.*—Vehicles provided with blackout lamps have a special blackout lamp switch which incorporates the operation of the service lamps and blackout lamps in one unit. This switch is shown in figure 120, with its connections to the various units in the lighting system. The plunger knob has **four** positions: off, blackout lamps, service lamps, **and service stop light only.** In its second position, the switch turns the blackout lamps on, keeping all other lamps off. The plunger knob cannot be pulled out to its third **or fourth** position until the safety lock button is pushed in. This is a safety feature to prevent any lights visible from above being accidentally turned on during a blackout. In the third position, the service lamps are on and operate **in the usual way** as described in *a* above. A trailer connection is provided to operate lamps on the rear of the trailer. Trailers are provided with **service tail and stop, blackout tail and stop, and sometimes blackout clearance** lamps.

[A. G. 062.11 (12-20-41).] (C. 1, Mar. 21, 1942.)

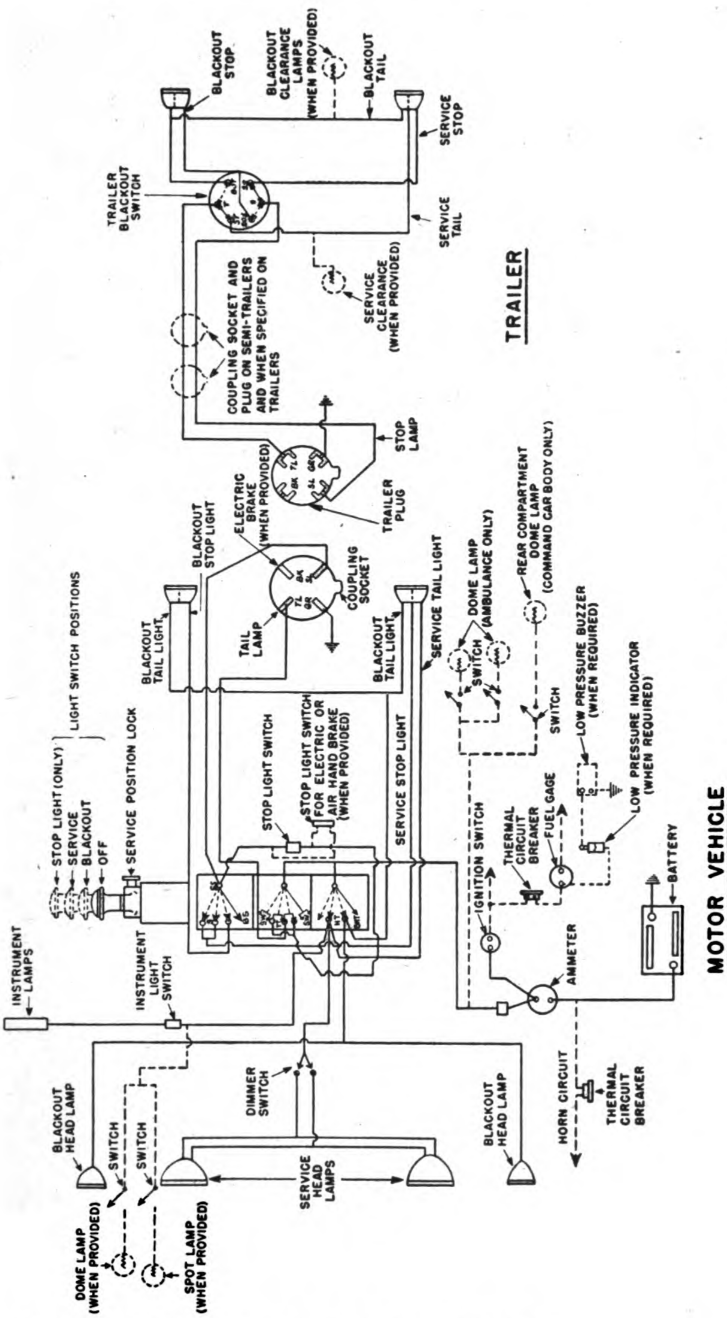


FIGURE 120.—Blackout lamp switch showing its connections.

[A. G. 062.11 (12-20-41).] (C. 1, Mar. 21, 1942.)

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G. C. MARSHALL,
*Chief of Staff.*

OFFICIAL:

J. A. ULIO,
*Major General,*
*The Adjutant General.*



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TM 10-580
C 2

TECHNICAL MANUAL

# AUTOMOTIVE ELECTRICITY

CHANGES No. 2

WAR DEPARTMENT,
WASHINGTON, June 9, 1942.

TM 10-580, January 29, 1941, is changed as follows:

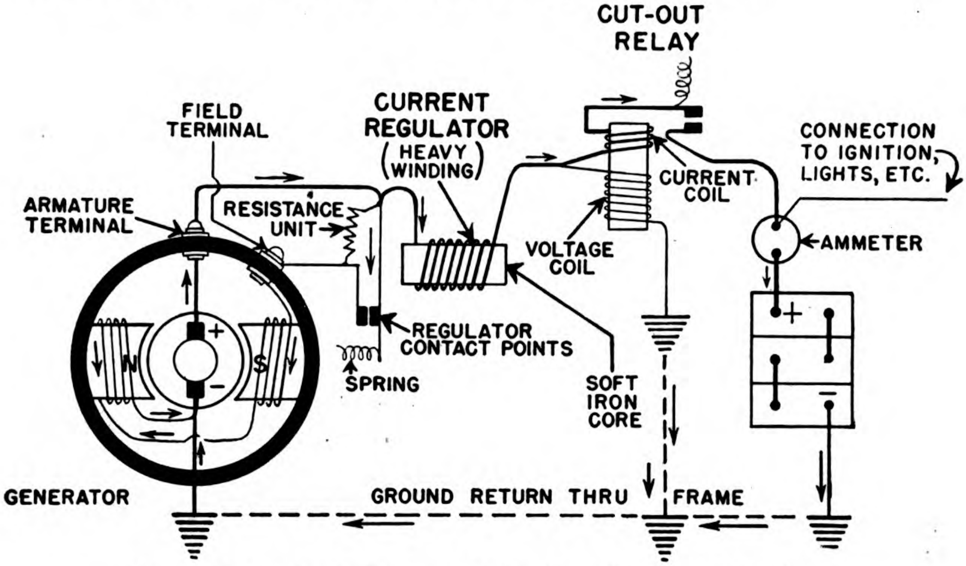


FIGURE 103.—Circuit diagram of vibrating relay current regulator.

[A. G. 062.11 (5-15-42).] (C 2, June 9, 1942.)

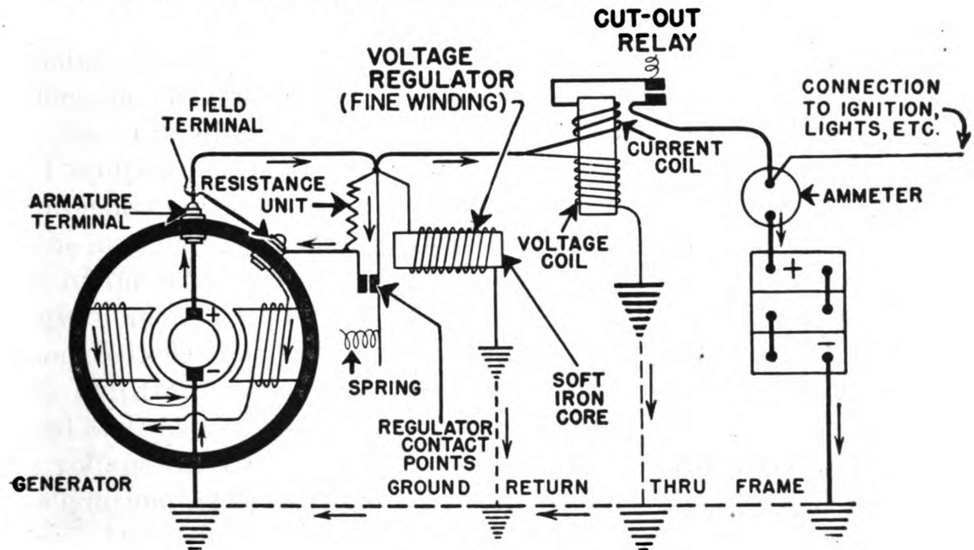


FIGURE 104.—Circuit diagram of vibrating relay voltage regulator.

[A. G. 062.11 (5-15-42).] (C 2, June 9, 1942.)

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TECHNICAL MANUAL

# AUTOMOTIVE ELECTRICITY

CHANGES No. 3

WAR DEPARTMENT,
WASHINGTON 25, D. C., 2 January 1945.

TM 10-580, 29 January 1941, is changed as follows:

**90. Automotive radio.**

* * * * *

*c. Interference.*—Rescinded.

SECTION IX (Added)

## SUPPRESSION OF INTERFERENCE IN AUTOMOTIVE RADIO





**91. General.**—Any spark created by the operation of electrical equipment, such as spark plugs, circuit breakers, coils, generators, regulators, magnetos, or distributor assemblies, by loose or dirty connections, or chafing of metal to metal, may cause interference with radio reception of nearby radio receivers. Since the units of the electrical equipment are connected by a wire or a series of wires, as in an automotive ignition system, the wiring acts as an antenna to transmit the interference created by the spark into the air. The capacitive effect of the wires and the spark-producing unit causes the radiated energy to affect a wide band of frequencies on a radio receiver with pronounced effects on certain frequencies.

**92. Ignition noises.**—*a.* When distributor breaker points are opened and closed by operation of engine, the ignition coil produces a high voltage current which flows across the gap in the spark plug to cause ignition. The sparks at the plugs and those at the breaker points cause violent surges of current to flow in all wires of the circuit (fig. 130). Around each wire, a magnetic field builds up and collapses with each make and break of the circuit. The rapidity of these changes in the magnetic field is governed by the engine speed.

*b.* The resultant noise in the receiver from breaker points, distributors, or spark plugs is recognized by clicking sounds which vary in rapidity and intensity with the speed of the engine.

*This change rescinds C 3, 10 November 1944. All copies of C 3, dated 10 November 1944, will be destroyed.

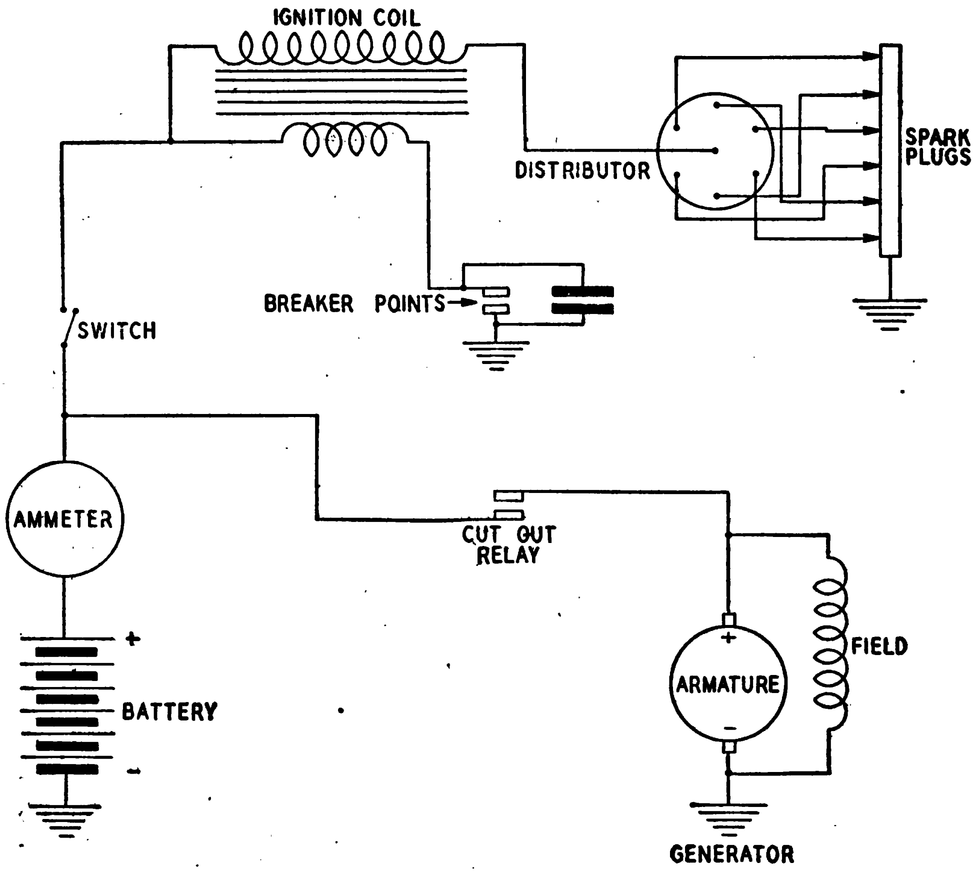


FIGURE 130.—Typical battery ignition system.

**93. Generator noises.**—*a.* With the generator in operation, there is some sparking between the brushes and commutator segments. Generators in good mechanical condition may exhibit some sparking which usually is not severe enough to cause radio interference. This type sparking is increased by any of the following mechanical defects:

(1) Brushes do not fit commutator.
(2) Brushes worn more than one-half original length.
(3) Incorrect brush spring tension.
(4) Collection of oil or carbon particles around commutator.
(5) Commutator worn out-of-round.
(6) Generator loaded in excess of rated capacity.
(7) Commutator segments burned or grooved.
(8) High insulation between segments of commutator.

*b.* Sparking between the brushes and commutator segments, may cause interference in nearby radio sets. This type of interference can be recognized by a roaring or whining noise which varies in pitch with the speed of the engine.

**94. Body noises.**—*a.* Body noises are produced by loose screws and bolts which allow various parts of the body to chafe against each other. This chafing produces static discharges which are a source of interference to radio receivers. Static charges caused by friction, and induced charges from wiring on the vehicles are collected by the vehicle body. These charges are retained by poorly grounded sections of the body until they build up to a sufficient value to jump to any well-grounded part of the vehicle. Each discharge causes a spark of sufficient intensity to create interference in a radio receiver. This type of disturbance is intermittent, varies in value, and can be detected by a frying or snapping sound. These effects are produced only when the vehicle is in motion, or for a very short period after the vehicle is stopped.

*b.* Looseness in the hood, brackets, and bolts can cause considerable noise in a receiver. This type of disturbance can be detected only when the vehicle is in motion, or by moving the loose parts. It can be recognized by a scratching sound in a receiver.

**95. Description of suppression methods.**—*a. General.*—There are various methods used to suppress radio interference caused by a vehicle. They are as follows:

(1) Resistor-suppressors.
(2) Condensers.
(3) Filters.
(4) Bonding.
(5) Shielding.

Application of one of the above methods is sufficient usually to adequately suppress the interference from any one source. In some instances it may be necessary to use a combination of the above methods to obtain the desired amount of suppression.

*b. Resistor-suppressors.*—A resistor-suppressor consists of a short carbon rod of high resistance, protected by a plastic cover. Resistor-suppressors are connected in the high-tension wires at the spark plugs and distributor to reduce the intensity of surges and thus eliminate interference from these sources. The resistance of the suppressors is high enough to control the surges but not high enough to affect the operation of the engine in any way.

*c. Condensers.*—These are units of metal foil separated by paper insulation and protected by a metal case. The case is filled with an impregnating compound to keep the moisture out. A wire connected to one side of the condenser is provided for connection to a circuit. The other side of the condenser is connected internally to the case. Surges created in the wiring by sparks at the generator brushes, regu-

lator, and gauge contacts are not as strong as those produced by the high-tension ignition circuit because the voltage is low, but they are strong enough to cause interference in a radio set. Resistor-suppressors cannot be used in these circuits because their resistance would reduce the low-voltage current too much. However, condensers, because of their inherent capacity, may be used to dissipate these surges. They are attached to the circuit as near as possible to the point at which the spark occurs. The case of the condenser is mounted on the metal frame of the unit causing interference, and the condenser wire is connected to the terminal. A condenser allows the interfering voltage to pass freely to ground (frame and body of vehicle), and at the same time prevents any loss of the useful direct current. Thus the surges are conducted away from the wiring and cannot cause interference.

*d, Filters.*—An assembly made of a closely wound coil of heavy wire and one or more condensers mounted in a metal container is called a filter. The condensers act in the same manner described previously, and the coil of wire acts to block the interfering voltage

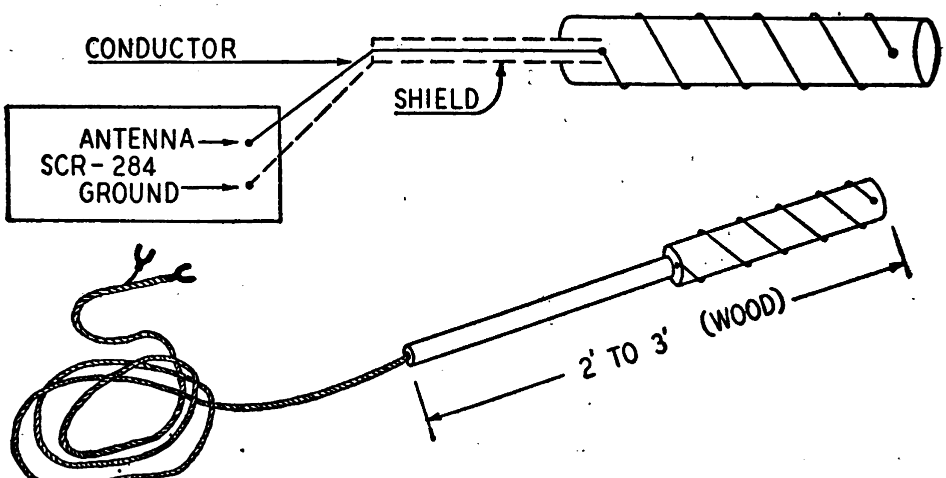


FIGURE 131.—Filters in typical battery ignition system.

from getting further in the circuit. Filters are used in some generator, regulator, and low-tension ignition circuits.

*e. Bonding.*—This term is applied to the method of electrically connecting individual metal sections to each other and to the frame or hull of the vehicle. Such bonding is necessary to provide an easy path for grounding static charges. Bonding is accomplished by internal-external toothed lock washers, and by bond straps. The better the connection between metal parts, the greater is the effect in preventing interfering waves from being thrown off to affect radio reception.

*f. Shielding.*—This term is applied to the method of covering all wiring carrying interfering voltages or surges with a metal shield. Woven metal conduit is used where flexibility is required, while solid conduit is used elsewhere. Units causing interference, such as spark plugs, ignition coil, distributor, and regulator, are inclosed in metal boxes. This shielding does not reduce the intensity of the interfering surges, but prevents their radiation. While such shielding is effective in preventing the radiation of interfering waves, filters and condensers are necessary to eliminate any interfering surges that would otherwise travel on the wires and affect the radio set through the power supply. Such filters and condensers are inclosed in metal shielding boxes provided with means of attachment to the conduit and shielding containing the connecting wires.

**96. Typical applications of suppression systems to vehicles.**—*a. Transport vehicles—ordinary suppression system.*—The system found on most vehicles consists of the following items:

(1) Resistor-suppressors are used in each high-tension lead from distributor to spark plugs. The suppressors are usually of a type that will slip over the terminal of the plug. The lead is screwed directly into the suppressor, thus locating the suppressor as close as possible to the spark gap in the plug.

(2) A resistor-suppressor is used in the high-tension lead from distributor to coil. This suppressor is placed in the lead as close as possible to the distributor. Usually it will be found about an inch or two away from the distributor.

(3) A filter is placed in the lead from the ignition coil to the ignition switch. This filter is mounted on the firewall where the lead goes through to the switch. Thus, the exposed lead between the filter and firewall is as short as possible. In later production vehicles, this filter is replaced by a condenser which is usually mounted on or near the coil, with its lead connected to the switch side of the ignition coil primary circuit.

(4) Filters are used in regulator circuits. One is usually connected between the battery terminal of the regulator and the ammeter, one is connected in the generator armature lead, and one is sometimes connected in the field lead between the generator and regulator. These filters are mounted on the firewall in such a position that the exposed leads leaving the filter are as short as possible. On certain vehicles, condensers (usually 0.1 mfd capacity) may be found at these points, mounted on the firewall, with the leads connected to the battery and generator armature terminals. A 0.01 microfarad condenser is sometimes applied with its lead connected to the field terminal of the regulator.

(5) A condenser is mounted on the generator with its lead connected to the output terminal. Condensers are used on certain lighting circuits, either mounted on the firewall or close to any junction point. The lead is connected to the circuit that may be carrying radio interference.

(6) Bonding straps will usually be found at the following places (there may be others):

(*a*) From hood to firewall.
(*b*) From hood top panel to hood side panel.
(*c*) From overhead valve covers to firewall.
(*d*) From engine block to frame.
(*e*) From fenders and fender skirt to frame.
(*f*) From radiator brush guard to frame.

(7) Bonding by means of internal-external toothed lock washers will usually be found at the following places:

(*a*) Under head of side panel mounting screws.
(*b*) Hood hold-down locks or latches.
(*c*) At gauge sending units.
(*d*) Under head of radiator grille mounting screws.
(*e*) Under head of fender mounting screws.
(*f*) Under head of any bolt or screw securing a separate section of metal that will help to form a shield in the vicinity of the engine compartment.

*b. Transport vehicles—Completely shielded suppression system.*—A few vehicles have a completely shielded system of suppressing, and, in such cases, usually only one filter is used. It is mounted in a metal box close to the regulator (it may be on the cab side of the firewall). A condenser will be found mounted on the generator, in a round metal shielding case. In most cases the only bond is between the engine and the frame.

*c. Tanks and armored cars.*—The resistor-suppressor system used on tanks with in line engines and most armored cars is basically the same as that used on transport vehicles described in *a* above. Usually there will be fewer bonds and toothed lock washers and more condensers. Less bonds and washers are needed because of the heavy, bolted, or welded construction of the hull or body. Resistor-suppressors, filters and condensers are used in the same circuits as in the transport vehicles. More condensers will be used to bypass the interfering surges from such accessories as auto-pulse fuel pump, electric gauges, windshield wipers, traversing motors, auxiliary generators and similar items. The condensers are always mounted close to the device causing interference, with the lead connected to the "hot" side

of the supply line. The complete shielding system is used on most tanks having radial engines and on some armored cars.

(1) In tanks, all wiring is inclosed in flexible metal conduit or solid metal conduit. Very little bonding is necessary with this system. In most cases only the engine is bonded to the support or hull. Control devices consisting of metal rods or tubing extending from crew compartment to engine compartment may be bonded at the point they enter the crew compartment.

(*a*) Usually one filter is used, inclosed in a shielding box. It is always mounted close to the regulator and the battery.

(*b*) Condensers are used on the electrical devices in the turret. They will be found at the brushes of the traversing motor, generator, and in the circuits of the stabilizer control switch box.

(2) In those armored scout cars and gun motor carriages which have the completely shielded system, all high tension, primary ignition, and charging circuit wiring is shielded with flexible metal conduit which is grounded every 2 feet with clips and internal-external toothed washers. The distributor, ignition coil, and regulator are shielded.

(*a*) Filters may or may not be used. If one is used, it will be mounted close to the regulator on the firewall.

(*b*) A condenser is mounted on the generator.

(*c*) Usually the only bond is that from engine to frame. Both sides of the engine are generally bonded.

**97. Method of locating source of noise.**—*a.* When interference is noticed, listen carefully to determine whether the interfering noise has one or more of the characteristics described below and note the probable source.

| *Noise heard* | *Probable source* |
|---|---|
| A regular clicking sound which varies with engine speed, and ceases the instant the ignition switch is turned off. | Ignition circuit (firing of spark plugs or opening of breaker points). |
| An irregular clicking sound that continues for a moment after the ignition circuit is turned off. | Regulator circuit (opening and closing of contacts). |
| A roar or whine that rises in pitch with increase in engine speed and continues for a moment after the ignition switch is turned off. | Generator (making and breaking of contact between brushes and commutator segments). |

*b.* A probe-type antenna, connected to a receiver, is helpful in locating the source of interference. Best results are obtained with an

amplitude modulated (AM) radio receiver such as the BC-312 or the receiver of the SCR 284 radio set. Probe-type antenna used with frequency modulated (FM) radio receivers such as in the SCR-608 and SCR-610 radio sets give unsatisfactory results. A probe-type antenna is illustrated in figure 132. It consists of 15 feet of shielded conductor (stranded) and a probe coil with four to eight turns of No. 14 or No. 18 wire, wound on a nonmagnetic core, between 1¼ inches and 2½ inches in diameter. One end of the winding is connected to the conductor of the shielded cable and the other end is dead. Fasten a short piece of wood to the coil end of the cable to provide a rigid handle and cover the entire length of coil and shielded cable with insulation or friction tape.

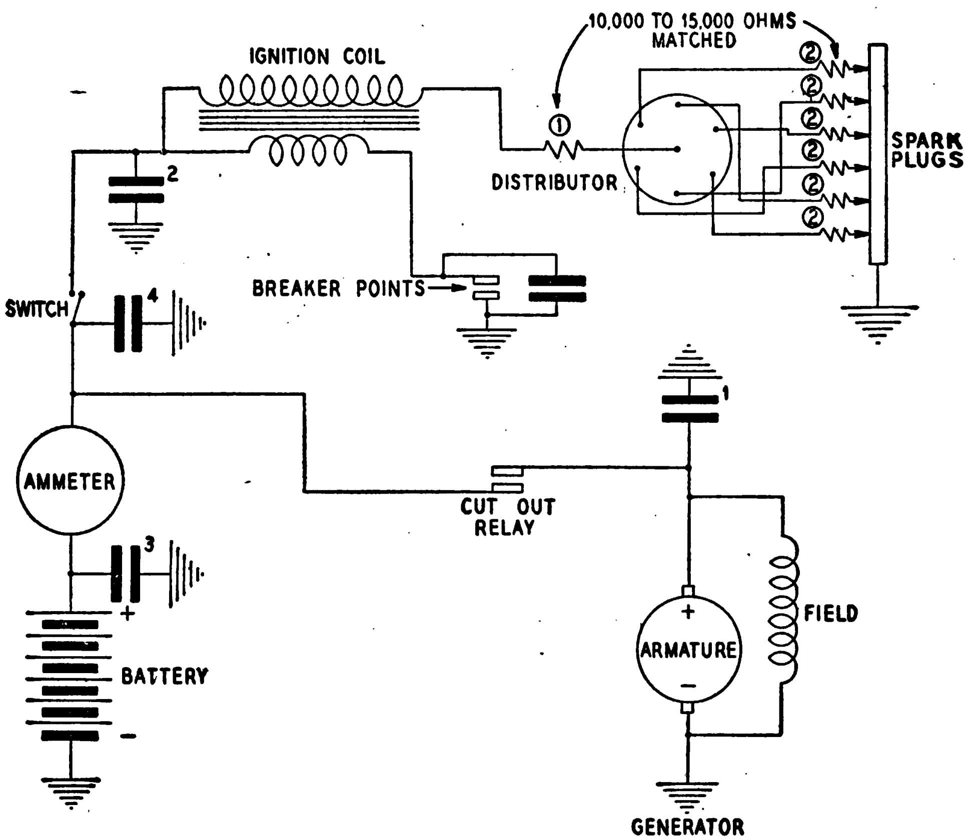


FIGURE 132.—Probe-type antenna.

*c.* If the ignition system is suspected of causing interference, place the coil of the probe close to the ignition coil, but not in contact, and move it along the wire connecting the ignition coil to the center of the distributor cap. Note any difference of intensity of interfering noise

in the receiver. Run the probe coil along each spark plug wire, starting at the distributor, and note any difference of intensity. If the noise is the greatest at the distributor, the fault is there; if it is greatest at one or more of the plugs, the plug is at fault.

*d.* If the generator circuit is suspected of causing interference, place the probe coil close to the generator housing, but not in contact with it, and move the probe along the wires from the generator to the voltage regulator. If the noise is strong at the generator and gradually diminishes toward the regulator, the generator is faulty.

*e.* The method outlined in *d* above is followed in checking any piece of equipment associated with the electrical system. It may be that some wires such as the tail or stop light wires, are picking up and reradiating the interfering noises. This can be detected by use of the probe coil.

*f.* To detect poor or broken bonding between the various parts of the vehicle, place the probe coil near the part that is suspected. Use a short length of wire or bonding braid to ground the suspected part or unit, and note if the interference is diminished. *Example: Place the probe coil near the side of the engine hood (hood closed) and note the intensity of the noise. With the probe coil in the same position, connect a test wire from the engine hood to a good ground. If the intensity of the interference is diminished, the hood bonding is not properly grounded.* The same test can be made on the driver's side of the firewall to determine if the choke and throttle control cables, steering column, etc., are properly bonded.

*g.* If the interference is encountered only when the vehicle is in motion, some of the body parts may not be bonded properly. Since the probe coil cannot be used satisfactorily under these conditions locate this type of interference by the process of elimination. Examine all parts of the body for evidence of poor bonding. Use bonding braid an any parts that are suspected. Sometimes it is possible to eliminate this type of interference by using a short length of wire to temporarily bond the various body parts while the vehicle is in motion. Whenever the use of the jumper wire decreases the intensity of the interference, bonding braid and external-internal tooth washers should be attached at that point.

**98. Remedies.**—*a.* Before attempting any suppression methods, perform the following:

(1) Inspect all bonding; connections must be clean and tight.
(2) Clean spark plugs and readjust gaps to specifications.
(3) Inspect and clean breaker points; adjust to specifications.
(4) Inspect and clean commutator and brush assembly of generator.

(5) Inspect all plug-in connectors on wires from distributor, and slip-on connectors at spark plugs.

*Note.* The connectors on distributor wires often become heavily oxidized. This condition will cause trouble in radio reception as well as in operation of the vehicle.

*b.* If the corrective measures listed above fail to cure the trouble, it will be necessary to replace the ignition suppressors or bypass condensers. If the vehicle has never been treated, suppressors of 10,000- to 15,000-ohm resistance should be installed. One suppressor is placed in the center wire of the distributor and one in each spark plug lead at the plug. Condensers should be connected to the generator armature, regulator, and battery terminals.

*c.* Figure 133 shows suppressors and condensers which, if necessary, must be installed. They are numbered in the order in which they should be installed. If the ignition system is in good condition and all principal parts of the vehicle bonded, it should not be necessary to install a condenser from ground to wires unprotected by fuses.

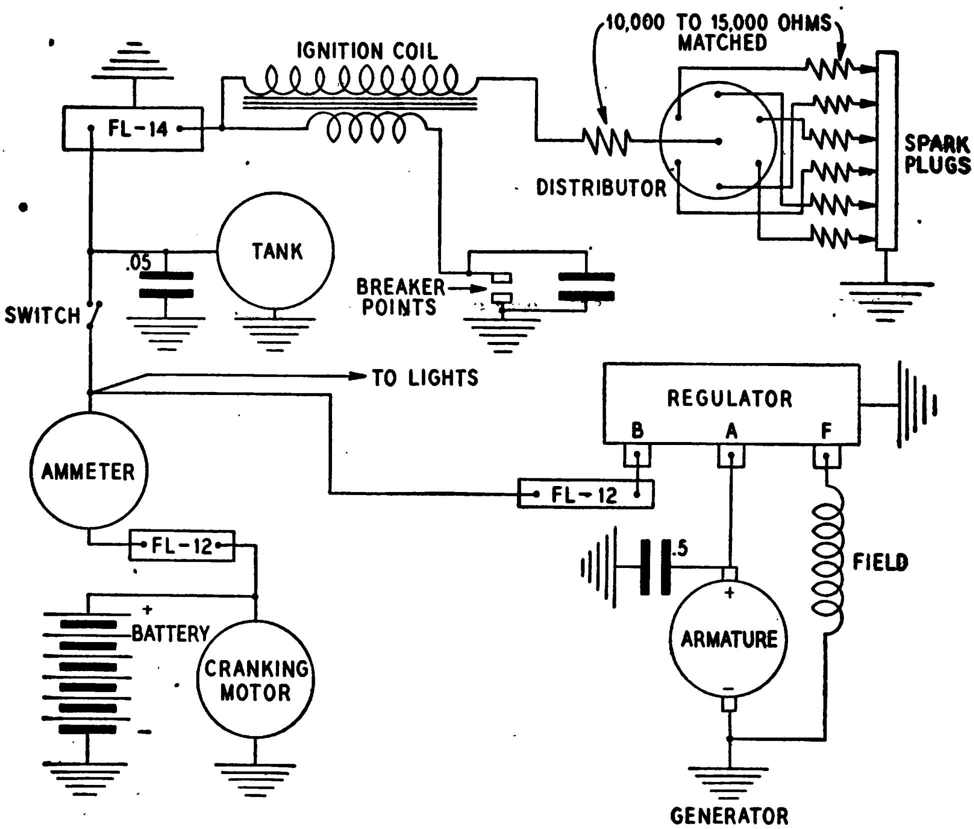


FIGURE 133.—Suppressors and condensers in battery ignition system.

**99. Maintenance of system.**—*a.* The maintenance of the suppression system consists of checking the component parts to see that

the mounting and connections are secure, that bonds are not loose or excessively worn, tightening bonds, screws, and bolts holding metal sections that may be loose. In general, this preventive maintenance can be performed at the same time other preventive maintenance operations are carried out. Thus, when the generator is checked, the condenser or filter connections and mounting on the generator are checked at the same time. The resistor-suppressors forming part of the high-voltage wiring can be checked at the time such wiring is checked.

*b. First echelon preventive maintenance service.*—In "During-Operation Service," a good driver will cooperate with the radio operator in determining whether or not the operation of the vehicle is causing interference in the radio equipment. Any noise present in the radio while the vehicle and engine are operating, but not present when the vehicle and engine are stopped, indicates a faulty suppression system. The fault should be located and remedied at the first opportunity.

*c. Second echelon preventive maintenance.*—(1) Preventive maintenance of the suppression system should be included in the regularly scheduled inspections and services performed on vehicles by operating organizations.

(2) The operations given below should be performed at the same time the unit or circuit covered by the item is being inspected. The item numbers refer to the scheduled maintenance operations for wheeled and half-track vehicles, covered in chapter 3, TM 9-2810.

(*a*) *Item No. 27—Generator, Cranking Motor and Switch.*—Tighten mounting bolt or bolts of condenser or filter. See that connecting wires are in good condition and secure.

(*b*) *Item No. 32—Coil and Wiring.*—Inspect resistor-suppressors, if used. Tighten connections. Inspect mounting and connections of condensers or filters.

(*c*) *Item No. 43—Regulator Unit (Connection, Voltage, Current and Cut-out).*—Check all mountings and connections of filters or condensers connected to regular terminals.

(*d*) *Item No. 79—Cab and Body Mountings.*—Tighten any bond straps between body and frame.

(*e*) *Item No. 94—Hood (Hinges and Fasteners).*—See that all bonding straps are tight and all contact bonds are clean and free from grease.

(*f*) *Item No. 95—Front Fenders and Running Boards.*—See that all bonding straps are tight and not excessively worn.

(*g*) *Item No. 104—Radio Bonding (Suppressors, Filters, Condensers, and Shielding).*—Check all suppression items not previously

checked. Eliminate any difficulties encountered by applying, with cooperation of the communication unit of the organization, the procedures covered in paragraphs 97 and 98.

(3) The items below refer to the scheduled maintenance operations for full-track and tanklike wheeled vehicles, covered in chapter 3, TM 9-2810.

(*a*) *Item No. 34—Generators and Cranking Motors.*—Check suppression condenser. See that mountings and connections are secure and clean.

(*b*) *Item No. 38—Ignition Wiring and Conduit.*—See that all resistor-suppressors, if used, are secure and not cracked or scorched.

(*c*) *Item No. 39—Coils (Standard) (Booster).*—Inspect ignition coils and radio noise suppressor condensers and be sure they are clean and that all mountings and connections are secure.

(*d*) *Item No. 51—Engine Compartment (Bulkhead and Control Linkage).*—Check any bonding straps between control linkage and bulkhead or hull.

(*e*) *Item No. 58—Engine Mountings.*—Check bonding straps.

(*f*) *Item No. 65—(Cranking Motor) (Primer) (Instruments).*—See that ground straps are in good condition, securely connected, and mounted.

(*g*) *Item No. 68—Regulator Unit (Connections) (Voltage) (Current) (Cut-out).*—See that connections and mountings of condensers or filters are secure.

(*h*) *Item No. 86—Wiring (Junction and Terminal Blocks and Boxes) (Fuzes and Spares).*—See that all connections are secure.

(*i*) *Item No. 87—Collector Ring (Brushes) (Leads) (Cylinder) (Cover).*—See that surfaces are clean.

(*j*) *Item No. 88—Radio Bonding (Suppressors) (Filters) (Condensers) (Shielding).*—Check all suppression items not previously inspected. Eliminate any difficulties encountered by applying, with cooperation of the communication unit of the organization, the procedures covered in paragraphs 97 and 98.

(4) The items below refer to the scheduled maintenance operations for the auxiliary generator, covered in chapter 3, TM 9-2810.

(*a*) *Engine (Crankcase) (Fan and Housing) (Cylinder Shield) (Mountings) (Exhaust Pipe and Heater Duct).*—See that ground straps are in good condition, securely connected and mounted.

(*b*) *Spark Plug (Gap) (Deposits) (Baffle).*—See that radio noise resistor-suppressor is in good condition, securely connected and mounted.

(*c*) *Magneto (Points) (Wiring) (Shield).*—When so equipped, see that condenser is in good condition, securely connected and mounted.

(*d*) *Generator* (*Commutator*) (*Brushes*) (*Control Box*) (*Wiring*).—See that radio noise suppression condensers on brush holding plate are in good condition and securely connected.

[AG 300.7 (23 Aug 44)]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL
*Chief of Staff*

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*The Adjutant General*

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For explanation of symbols, see FM 21-6.



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# AUTOMOTIVE ELECTRICITY

**Prepared under direction of The Quartermaster General**



## SECTION I

## GENERAL



**1. General.**—Electricity, because of its various applications, plays a major role in the operation of modern motor vehicles. Its principal function is to supply a spark for igniting the fuel charge in the cylinders of internal combustion engines. The performance obtained from the modern automotive engine is largely due to the improved ignition of the fuel charge obtained by better electrical equipment. With the development of various electrical units, the scope of the automotive electrical system has increased until it does many things besides igniting the fuel charge, such as cranking the engine and operating lights, horns, gages, and numerous accessories.

**2. Automotive electrical systems.**—Automotive electrical units are grouped in systems according to their functions. These systems, which will be discussed in the following order, are the—

*a.* Ignition system.

*b.* Starting and generating system.

*c.* Lighting system.

*d.* Miscellaneous systems (other electrical units).

**3. Source of electrical energy.**—To operate the units in the various systems, some source of electrical energy is necessary. Motor vehicles generally use a storage battery for this purpose. A battery has potential chemical energy which is transformed into electrical energy that fires the fuel charge in the engine cylinders to keep the engine operating, operates a starting motor for cranking the engine, and operates the lights and other units. A supply of chemical energy is maintained in the storage battery by the charging current from a generator driven by the engine. When only an ignition system is desired, a magneto is used as a source of energy. Magnetos supply energy only when driven by the engine.

**4. Knowledge of fundamentals.**—Because of the many controls and adjustments necessary to operate electrical equipment correctly, a substantial proportion of minor vehicular troubles are due to defects or maladjustments in the electrical system. It is necessary to be thoroughly familiar with the fundamentals of electricity and magnetism, on which the operation of all electrical units depends, in order to understand the functions of the electrical units, know their relation to the operation of the vehicle, and maintain and repair them successfully.

**5. Electrical terminology.**—For purposes of clarity and ready reference the following terms are defined:

*A. C.*—Alternating current. A current which changes its direction of flow in a regular, established sequence.

*Ampere.*—A unit for measuring the rate of flow of electricity. The current produced by a potential of 1 volt impressed across a resistance of 1 ohm.

*Ampere turns.*—Magnetizing force of a coil. The number of amperes flowing in a coil multiplied by the number of turns of wire in that coil.

*Bypass.*—A separate passage which permits a liquid, gas, or electric current to take a course other than that normally used.

*Circuit.*—The entire course through which an electric current flows.

*Clockwise.*—Rotation in the same direction as the hands of a clock.

*Coil.*—A conducting wire wound upon a spool or core to save space, as in a resistance coil; or to concentrate or multiply the effect of an electric current, as in an induction coil or armature.

*Conductor.*—A material through which electricity will readily flow.

*Core.*—An iron mass, generally the central portion of an electromagnet or armature around which the wire is coiled.

*Coulomb.*—The practical unit for measuring the quantity of electricity. The amount conveyed by a current of 1 ampere intensity in 1 second.

*Counterclockwise.*—Rotation in a direction opposite to that of the hands of a clock. Anticlockwise means the same.

*Cumulative winding.*—Two coils of wire wound so that the strength of their magnetic fields is added.

*Current.*—The flow of electricity.

*Cycle.*—A series of events, operations, or phenomena that repeat themselves in an established sequence. A complete period of change in direction and magnitude of an alternating current.

*D. C.*—Direct current. A current which flows in one direction only.

*Depolarizer.*—A substance used to counteract the formation of a film of gas upon one of the elements of a battery cell.

*Dielectric.*—A nonconductor or insulator; a substance which transmits electric forces or effects by induction rather than by conduction.

*Differential winding.*—Two coils of wire wound so that the strength of their magnetic fields is subtracted.

*Dynamic electricity.*—Current electricity, or electricity in motion.

*Eddy currents.*—Currents which are induced in an iron core and circulate within it.

*Electrical system.*—Usually consists of the starting, lighting, ignition, generating, and horn circuits, and includes all electrical units of each circuit.

*Electrolyte.*—A conducting liquid which is decomposed by the passage of an electrical current. It is usually a solution of acid and water.

*Electromagnet.*—A magnet formed by passing a current of electricity through wire wound around a core.

*Electromagnetic wave.*—Electricity radiated by some kind of ether disturbance.

*Electromotive force* (E. M. F.).—Potential, or dynamic electrical pressure.

*Energy.*—Capacity for doing work, measured in work units. Mechanical energy is a product of force and distance; electrical

energy is a product of potential difference and quantity. The watt (power unit) indicates the rate of expenditure or of production of electrical energy.

*Field.*—A space influenced by magnetic lines of force, as a generator field.

*Focal point.*—The principal focus. The point at which light rays parallel to the axis of a lens or reflector are brought together.

*Generator.*—A machine which, through the agency of electromagnetic induction, converts mechanical energy into electrical energy.

*Ground.*—Connection of an electrical unit to the engine, frame, etc., to return the current to its source.

*High tension.*—A term used to express relatively high potential (electrical pressure).

*Hydraulic analogy.*—A method of explaining electrical theory by using the flow of water for a comparison.

*Insulation.*—A protective covering on wires or electrical parts to prevent short circuits.

*Kilowatt.*—1,000 watts (approximately 1⅓ horsepower).

*Laminated.*—Divided into thin sheets, leaves, or plates.

*Lines of force.*—Invisible lines in a space (field) along which magnetic forces flow.

*Low tension.*—A term used to express relatively low potential (electrical pressure).

*Magnet.*—A material that has the ability to attract and repel iron.

*Magnetic field.*—The space around a magnet through which the magnetic lines of force travel.

*Magnetic flux.*—The flow of magnetism.

*Motor.*—A machine which, through the agency of electromagnetic induction, converts electrical energy into mechanical energy. Technically applies to an electric motor. Usage also applies it to the power plant of a motor vehicle. However, the term "engine" should be used in referring to the power plant of a motor vehicle to avoid confusion.

*Negative.*—A term designating the point of lower potential when the potential difference between two points is considered.

*Negative terminal.*—The usually accepted terminal to which the current returns after passing through the circuit.

*North pole.*—The pole of a magnet from which the lines of force emanate (or leave).

*Ohm.*—A unit of measurement of electrical resistance. A conductor of 1 ohm resistance allows 1 ampere of current to flow when 1 volt potential (pressure) is impressed on it.

*Parabolic reflector.*—A reflector that sends all reflected light originating from the focal point outward in parallel rays.

*Positive.*—A term designating the point of higher potential when the potential difference between two points is considered.

*Positive terminal.*—The usually accepted terminal from which the current enters the circuit.

*Potential.*—Electrical pressure, measured in volts.

*Prismatic lens.*—A lens with parallel grooves or flutes which deflect and distribute light rays.

*R. p. m.*—Revolutions per minute.

*Residual magnetism.*—The magnetism retained by a material after all magnetizing forces have been removed.

*Rheostat.*—A variable resistance controlled by a sliding contact.

*Short circuit.*—A circuit, purposely or accidentally made, through a small resistance which acts as a shunt to a circuit of comparatively large resistance.

*Shunt.*—Parallel connection with a portion of a circuit.

*Solenoid.*—A coil of wire which exhibits magnetic properties when an electric current is passed through it.

*South pole.*—The end of a magnet at which the lines of force enter (or return). Opposite to north pole.

*Specific gravity.*—The weight of a substance compared to the weight of an equal volume of chemically pure water at 4° C. (39.2° F.).

*Static electricity.*—Accumulated stationary electrical charges which are generated by friction.

*Stroboscopic.*—Intermittent illumination of a moving object, giving the illusion that the object is standing still.

*Sulphation.*—A crystalline formation of lead sulphate on storage battery plates.

*Synchronize.*—To make two or more events or operations occur at the proper time with respect to each other.

*Torque.*—A twisting or wrenching effort. Expressed as the product of the force and the perpendicular distance from the center of rotation at which this force is exerted.

*Vacuum.*—Space from which air has been removed, resulting in less than atmospheric pressure.

*Volt.*—A unit of measurement of potential or electrical pressure. The potential necessary to send a current of 1 ampere through a conductor of 1 ohm resistance.

*Watt.*—A unit of measurement of electrical power. One watt of power equals 1 ampere of current times 1 volt potential.

## Section II

## PRINCIPLES OF ELECTRICITY AND MAGNETISM



**6. Nature of electricity.**—*a.* The exact nature of electricity is not known. However, its effects, the laws governing its action, and the methods of controlling and using it are well understood.

*b.* All matter is thought to be composed of positive and negative charges. A charge, either positive or negative, is the keynote of all electrical phenomena. When a body is in a stable state, the positive and negative charges neutralize each other and the result is a normal or zero potential. A body electrically charged is one with a potential above or below the normal or zero potential.

*c.* The earth may be considered as an ocean of electricity in that it is the level toward which all electricity flows, in the same way that all water flows to the level of the ocean. Any electrically charged body put into communication with the earth will in a period of time be reduced to the standard or zero potential of the earth, just as water anywhere on earth will eventually find its way to sea level.

**7. Positive and negative charges of electricity.**—Since the zero of potential is arbitrarily taken as that of the earth, bodies can be excited to bear opposite charges of electricity not only to each other but to the earth. One body cannot be charged with a quantity of positive electricity without an equal charge of negative electricity being established somewhere else, or vice versa. Because the sum of all equal positive and negative quantities is zero, the sum of all elec-

trical charges in the universe is zero. This doctrine of electricity is comparable to the law of conservation of energy.

**8. Forms of electricity.**—Electricity, according to the nature of its effect, is found in three forms; static, dynamic, and electromagnetic wave.

*a. Static.*—(1) Static electricity is the result of charges being held upon bodies and discharged intermittently. These charges are generated by friction between certain materials; for example, glass and silk. The electricity thus produced normally remains at rest but it will readily dissipate its energy when allowed to discharge to some other body or to the ground. The dissipation of static electricity can be illustrated by bringing a finger close to a rapidly moving leather belt running over a pulley. A momentary spark of considerable intensity will jump from the belt to the finger.

(2) The static charges which accumulate on a vehicle must be considered when filling a gasoline tank or when hauling gasoline. The nozzle on a gasoline hose should be in contact with the filler opening on a vehicle before gasoline is pumped into the tank in order to ground the accumulated static charges. A chain dragging from a gasoline truck permits accumulated charges to pass safely to the ground without sparking. Sparks from such accumulated charges have resulted in disastrous accidents.

*b. Dynamic.*—Dynamic electricity is the result of charges continuously supplied and discharged. It is electricity in motion, or current electricity generated by chemical cells, generators, and magnetos. It is capable of doing work and is used in the operation of automotive electrical equipment, such as the starting motor, lights, etc. This manual deals with this form of electricity.

*c. Electromagnetic wave.*—An electromagnetic wave or ether disturbance, commonly known as a radio wave, is a radiated form of electrical energy. This form of electricity is used in wireless telegraphy, and to some extent in medicine. It has not yet been used in motor vehicles except in vehicle radios. It is possible that further research will develop uses for it in the automotive field.

**9. Hydraulic analogy.**—*a.* Dynamic electricity flows in a stream or current similar to the flow of water. An electric current flowing through a wire may be compared to water flowing through a pipe. Water flows through a pipe if there is a difference in pressure between the two ends, as in figure 1①. In this case, the difference in pressure is caused by a difference in level between *A* and *B*. In the same manner, electric current will flow through a wire if there is a difference in

potential (electrical pressure) between the two ends, as there is between the *A* and *B* terminals of the battery in figure 1②.

*b.* The *A* terminal of the battery is assumed to have a positive charge of electricity and the *B* terminal a negative charge of electricity. Using positive and negative for the potential values of the charges gives a convention for fixing the direction of electric current. An electric current is assumed to be a discharge from positive to negative just as water flows from high to low levels. The greater the difference in water level the greater will be the tendency of the water to seek the same level. The same applies to the electric charge. This difference in charge is termed difference in potential, or potential difference, and the terms high or low potential indicate a large or small difference of charge.

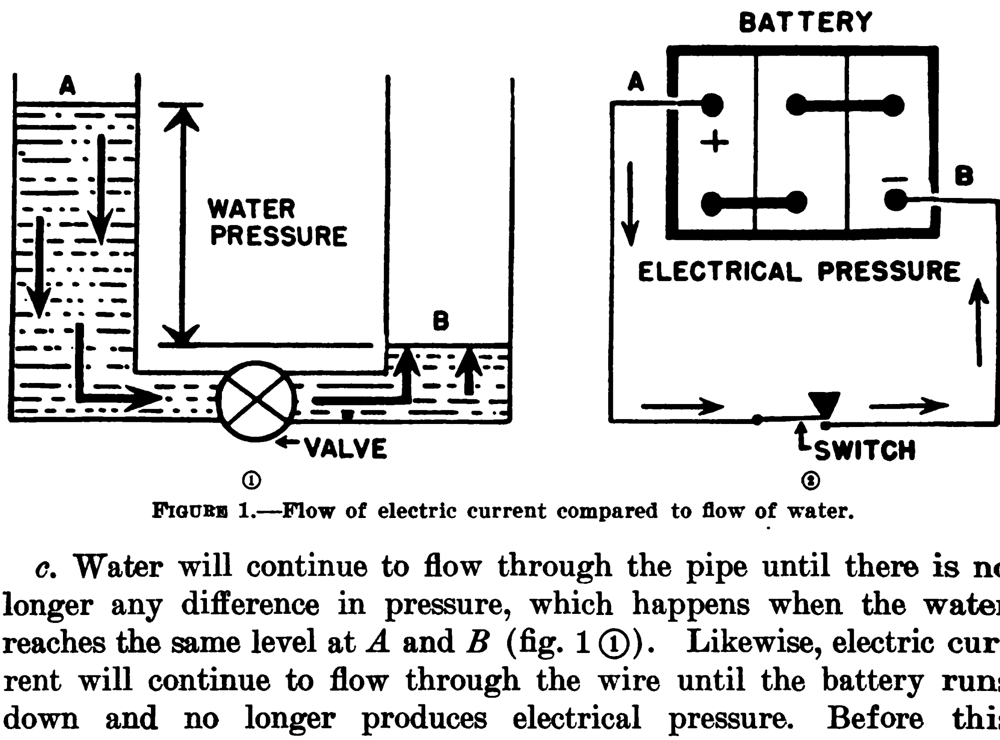



FIGURE 1.—Flow of electric current compared to flow of water.

*c.* Water will continue to flow through the pipe until there is no longer any difference in pressure, which happens when the water reaches the same level at *A* and *B* (fig. 1 ①). Likewise, electric current will continue to flow through the wire until the battery runs down and no longer produces electrical pressure. Before this pressure is lost, the flow of electric current can be stopped by opening the switch just as the flow of water can be stopped by closing the valve.

*d.* Water can be forced to flow through a pipe by means of the pressure developed by a pump (fig. 2) and electric current can be forced to flow through a conductor by means of pressure developed by an electric generator (fig. 3).

*e.* The total pressure that makes water flow is measured in pounds and the rate of flow in gallons per unit of time; whereas, in an elec-

trical circuit the pressure or electromotive force is measured in volts and the rate of flow in coulombs per unit of time. A coulomb is the unit of electrical quantity similar to the gallon. Since electrical measurements are usually made of the rate of flow and not of the quantity, the ampere (which is 1 coulomb per second) is the unit commonly used. Some comparisons between hydraulic and electrical terms (fig. 4) illustrate the meaning of common electrical terms.

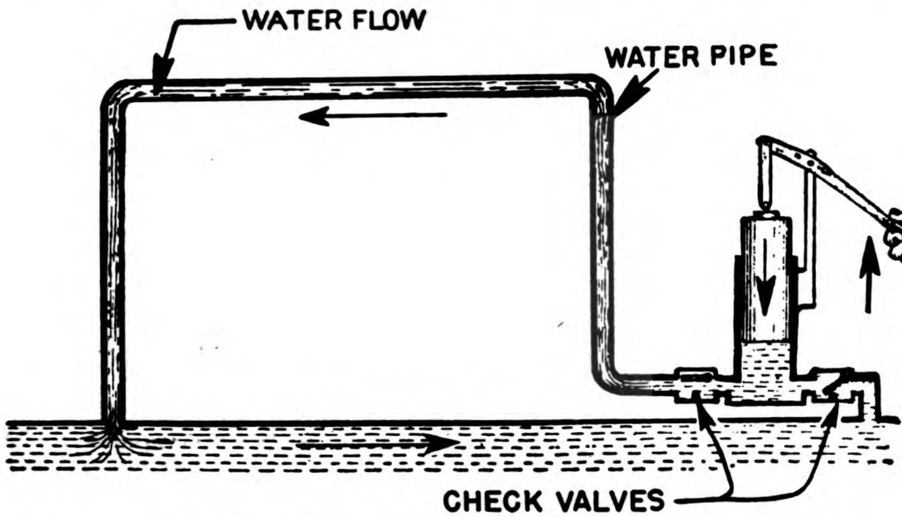



FIGURE 2.—Pressure from pump causes water to flow in pipes.

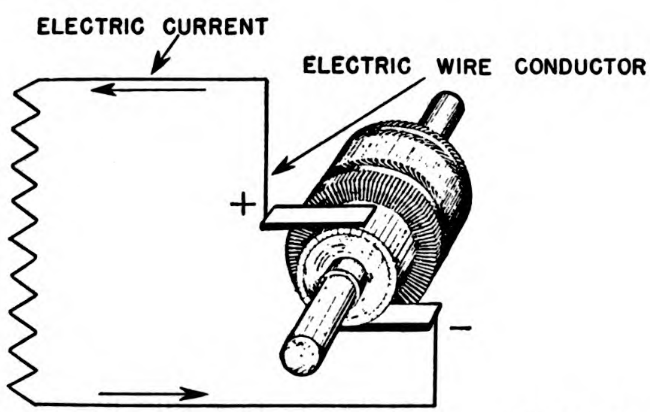



FIGURE 3.—Electrical pressure from generator causes current to flow in circuit (wires).

**10. Conductors and insulators.**—*a.* All substances conduct electricity to some extent, yet all offer a certain resistance to the flow of electricity. Any substance offering comparatively little resistance to the flow of current is known as a conductor. The ability of a susbtance to conduct a current (conductivity) depends upon its composition and purity. A few of the most common conductors, in the

order of their conductivity, are silver, copper, aluminum, zinc, brass, nickel, iron, platinum, tin, and lead. Copper, because of its relative cheapness, low resistance, and high breaking strength is recognized as the best all around commercial conductor and is used universally in the construction and wiring of automotive electrical equipment.

*b.* Substances offering much resistance to the flow of electricity, for example, glass, mica, bakelite, rubber, porcelain, and fiber, are known as nonconductors or insulators. A conductor covered with insulating material, such as rubber, cotton, silk, and enamel, is known as an insulated conductor.

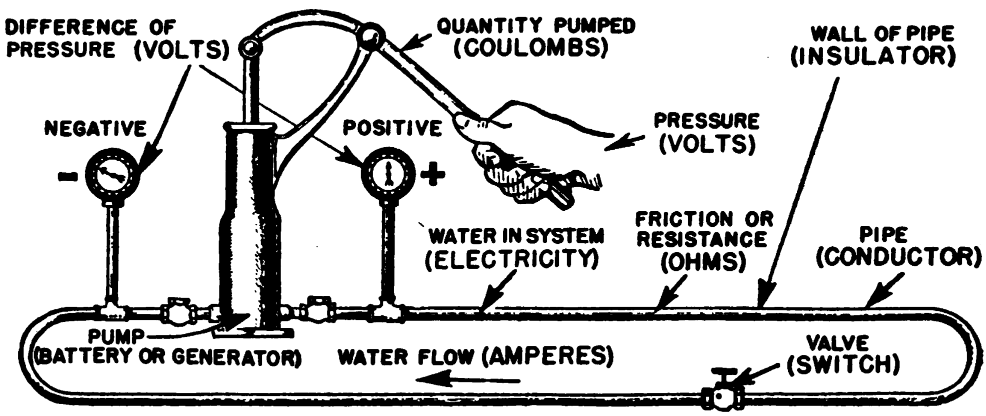



FIGURE 4.—Comparison of hydraulic with electrical terms.

*c.* A liquid that will conduct electricity, such as a solution of sulphuric acid and water, and which is decomposed by the passage of an electric current, is called an electrolyte. A liquid such as pure water, which does not readily conduct electricity, is known as a non-electrolyte.

**11. Resistance.**—*a.* The resistance of a conductor may be compared to the friction offered between a pipe and the liquid flowing through it. The electrical resistance of a conductor depends upon its size, length, material, and temperature, just as the hydraulic resistance of a pipe depends upon its size, length, material (whether smooth or rough), and temperature. It is thus evident that the size of a certain wire determines the amount of current it can carry. If the current is excessive, the wire will overheat. A small wire can conduct a small current, while a large wire is required to conduct a large current, just as a large pipe is required to conduct a large flow of water. The resistance of a conductor increases as its length increases, and decreases as its size, diameter, or cross sectional area increases.

*b.* The electrical resistance of a conductor is measured in ohms. A conductor with 1 ohm resistance allows 1 ampere of current to flow when a pressure of 1 volt is applied across its ends. From a practical point of view, it should be remembered that the resistance offered by 1,000 feet of No. 10 B & S gage copper wire (approximately $\frac{1}{10}$ inch in diameter) is almost exactly 1 ohm.

**12. Ohm's law.**—A definite relation exists between the current, the voltage, and the resistance of a circuit. This relation is known as Ohm's law, which says the electric current in a conductor equals the voltage applied to the conductor divided by the resistance of the conductor. This law may be simply stated: $\text{Current}=\frac{\text{voltage}}{\text{resistance}}$ or using units, $\text{Amperes}=\frac{\text{volts}}{\text{ohms}}$. Representing the law by use of symbols, $I=\frac{E}{R}$ in which $I$ is the current in amperes, $E$ the voltage or electromotive force in volts, and $R$ the resistance in ohms. By transposing, this formula may be expressed in other forms.

*a.* To find voltage: $E=I\times R$

*b.* To find resistance: $R=\frac{E}{I}$

**13. The voltmeter and ammeter.**—*a.* The voltage and current of a circuit can be readily measured by a voltmeter and an ammeter.

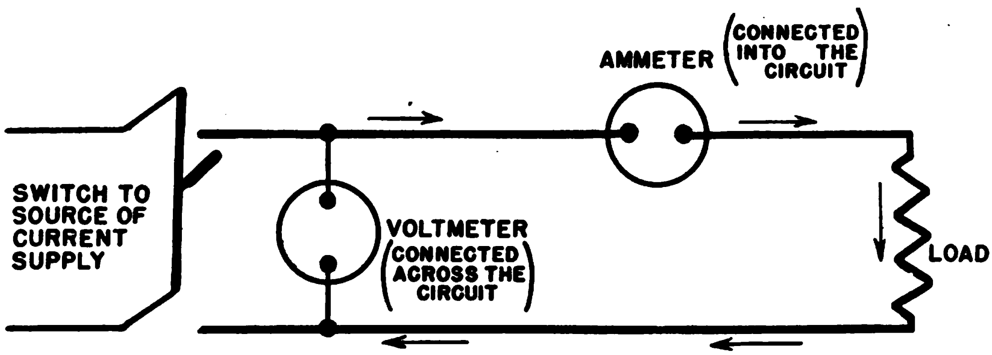



FIGURE 5.—An ammeter and a voltmeter connected in an electrical circuit.

Although the two instruments are often similar in external appearance, they differ mainly in the size of wire used for the operating coil. The voltmeter, containing a coil of many turns of small wire, measures the electrical pressure in volts and is connected directly to the terminals between which the voltage is to be measured; the ammeter, containing a coil of few turns of large wire, measures the current flow in amperes and is inserted in the circuit so the current will flow through it. (See fig. 5.) A motor vehicle is usually

equipped with an ammeter only, the voltmeter being used chiefly for testing purposes. The ammeter, located on the instrument panel, is connected to the battery charging circuit so that it will indicate the amount of current either charging or discharging from the battery, with the exception of the current supplied to the starting motor because of the magnitude of this current.

*b.* The electrical resistance of a circuit can be calculated by measuring the voltage and the current and dividing the voltage in volts by the current in amperes. A resistance meter that directly measures the resistance of a circuit has been developed. Actually, this instrument is very similar to the voltmeter since it measures resistance by comparing the voltage across the unknown resistance with that across a fixed and known resistance within the instrument when the same current flows through both. The current that flows through the resistance to give a reading is usually supplied by dry cells within the instrument.

**14. Electrical power.**—*a.* Work is done when energy is expended. Power is the rate at which this energy is expended and is independent of the total work to be done. The unit of electric power is the watt. One watt is defined as the power available when 1 ampere of current flows through a 1-volt circuit. Stated as a formula, power=voltage×current or using units, watts=volts×amperes. This is sometimes expressed by using symbols, as: $P=E\times I$

*b.* As an example, the power required from a 6-volt battery to supply a current of 2 amperes to the primary ignition circuit would be a $6\times2=12$ watts. The watt is often too small a unit for convenient use, so a kilowatt (kw) or 1,000 watts is frequently used.

*c.* Some important relations in electrical power are:

1 horsepower=746 watts or 0.746 kilowatt.

1 kilowatt=1.34 horsepower.

1 kilowatt of power used for 1 hour=1 kilowatt hour.

**15. Effects of electric current.**—Experiments show that an electric current in flowing through certain circuits produces various physical, chemical, magnetic, and physiological changes or effects.

*a. Heat and light.*—Heat is developed to some extent in any conductor through which electricity flows. The amount of heat developed depends upon the amount of current flowing and the resistance of the conductor. If the flow of current is sufficient, the conductor may become hot enough to glow with a white heat and give off light as it does in incandescent lamps. The heating effect of electric current is used in electric irons and toasters; and on the automobile in electrically operated carburetor heating devices and cigar

lighters. The fuzes used in lighting and generator circuits burn out (when the temperature of the fuze wire reaches the melting point) and open the circuits to protect them against possible damage. In all cases, the heat produced in the conductor represents the use of electrical energy.

*b. Chemical effect.*—The chemical effect of an electric current may readily be seen by connecting wires to the two terminals of a storage battery and submerging the free ends in a glass of water in which a little table salt has been dissolved. Current passing through the liquid causes the water ($H_2O$) to break up into its two component gases, hydrogen (H) and oxygen (O). The hydrogen gas accumulates in fine bubbles around the negative wire and the oxygen goes to the positive wire. Since there are two parts of hydrogen produced to one of oxygen, and since the oxygen combines readily with the metal of the positive wire (especially if copper wire is used), the gassing will appear to take place chiefly around the negative wire (figure 6). This fact provides an easy method of distinguishing the positive and the negative polarity of live wires and determining whether the current supply is direct or alternating. In the case of alternating current, the same amount of gas will collect around both electrodes because alternating current is constantly changing its direction of flow.

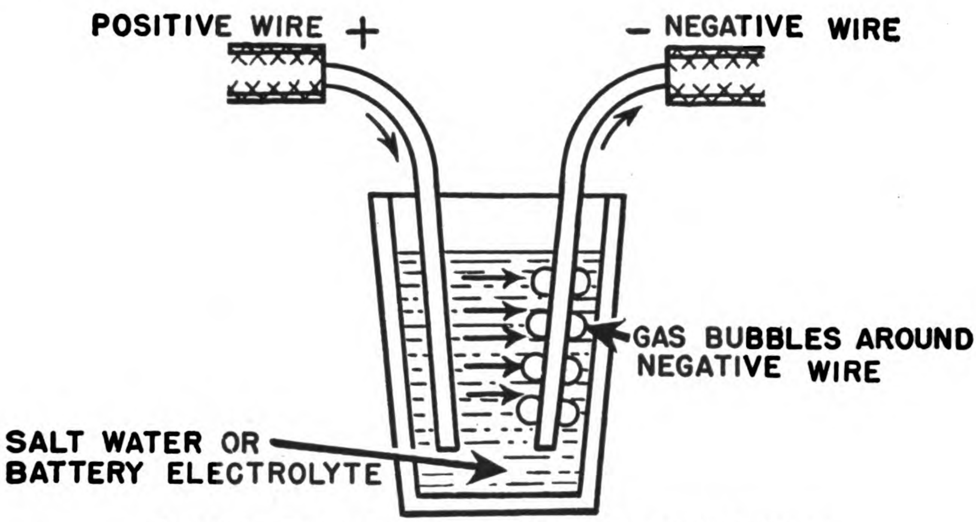



FIGURE 6.—Example of chemical effect of an electric current.

*c. Magnetic effect.*—The magnetic effect of an electric current may be readily demonstrated by holding a magnetic compass needle near a wire that is carrying current from a battery; for example, one of the headlight wires on an automobile. When the switch is turned on,

the current passing through the wire from the battery to the lamp will cause the compass needle to turn at right angles to the wire. The magnetic effect may also be demonstrated by sending a current from a battery through a coil of insulated wire wound around an iron bar and noting the attraction the iron bar has for other pieces of iron. The iron bar is said to be magnetized and the strength and direction of this magnetism is in direct relation to the amount and direction of current flowing.

*d. Physiological effect.*—The physiological effect of electric current is demonstrated by the reactions of a human being when the hand or other part of the body comes in contact with a high voltage conductor, such as a spark plug terminal. This physiological effect has no commercial value in the automobile, but it has been utilized by the medical profession for the treatment of certain ailments.

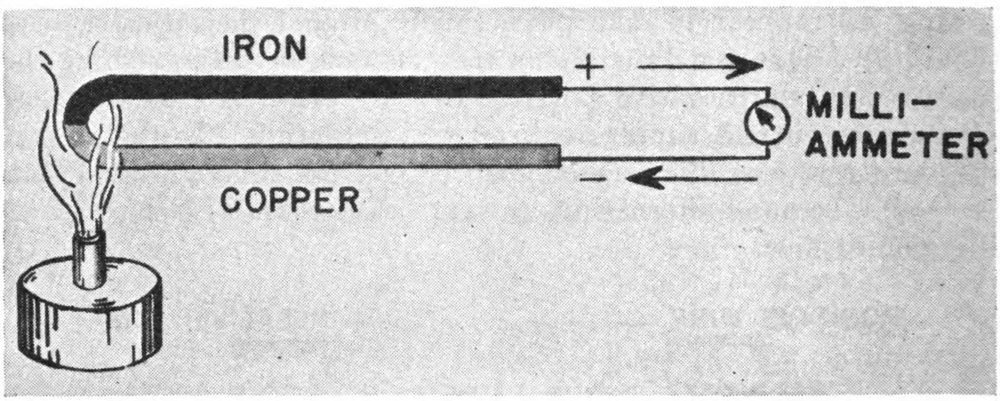



FIGURE 7.—Thermal production of electric current.

**16. Methods of generating electric current.**—An electric current may be produced by thermal (heat), chemical, or mechanical means.

*a. Thermally.*—The conversion of heat into electrical energy is demonstrated by the thermocouple. Heat applied to the junction of two dissimilar metals, for example, iron and copper, will produce a relatively small electric voltage across the outer ends (fig. 7). If the two ends are connected by a wire, a current will flow through it from the iron to the copper, which can be measured by the milliammeter. The milliammeter is a low-range ammeter for measuring thousandths of an ampere. The voltage is produced by the difference in the heat conductivity of the two metals. It is proportional in value to the difference in temperature at the junction and outer ends of the metals. The pyrometer, which is a complete thermocouple instrument for measuring high degrees of heat, plays an important part in automo-

bile manufacture, especially in controlling the heat treating of steel parts.

*b. Chemically.*—(1) The production of electric current by chemical action is perhaps the oldest known method of producing dynamic electricity. If two different elements are placed in an acid solution which acts chemically upon one element faster than upon the other, a difference in voltage or electrical pressure will be produced, and if these two elements are connected externally by a wire, an electric current will flow through the circuit. This is the basic principle of the dry cell and the storage battery.

(2) A cell consisting of a plate of copper and a plate of zinc placed in a solution of 10 percent sulphuric acid and 90 percent water is shown in figure 8. Since the chemical action of the acid upon the zinc is more intense than upon the copper, an electric pressure is set up with the zinc plate becoming negative in value and the copper plate positive. If an external circuit is connected to the two plates, an

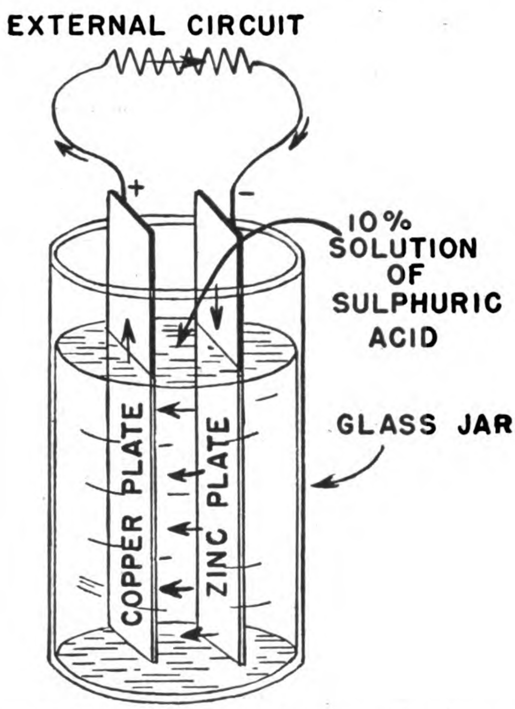



FIGURE 8.—Chemical production of an electric current.

electric current will flow through the external circuit from the copper to the zinc and through the solution from the zinc to the copper as indicated by the arrows.

*c. Mechanically.*—If an electric conductor and a magnetic field are moved in relation to each other, an electric current will be generated

in the conductor. This is accomplished in the magneto and generator. (See secs. V and VI.)

**17. Sources of current for automotive purposes.**—Current is supplied for automotive purposes by a battery and a generator, or a magneto.

*a.* A battery is either a primary (dry) cell which destroys itself to produce current, and is then discarded; or a secondary (storage) cell which is charged from an outside source of current to return its elements to their original state after they have produced current by chemical changes.

(1) *Dry cell.*—The dry cell is especially adaptable to ignition systems of the open circuit type where the current demand is small. A commercial dry cell, shown in cross section in figure 9, consists of a

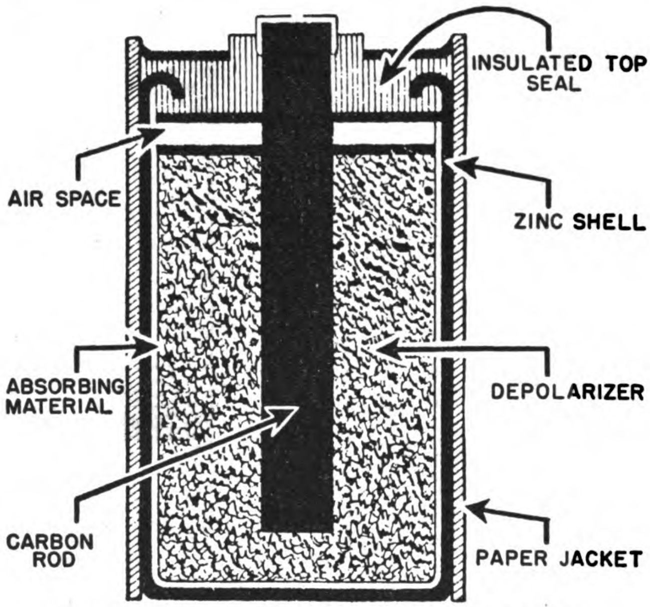



FIGURE 9.—Sectional view of a dry cell battery.

cylindrical negative zinc shell with a positive carbon rod placed in the center of it. A layer of absorbent material (usually blotting paper or a prepared paste) is placed around the inside of the zinc shell to separate the two active elements. The space between the absorbing material and the carbon rod is filled with a mixture of powdered carbon and manganese dioxide. Such a mixture, known as a depolarizer, counteracts the accumulation of hydrogen gas bubbles around the carbon positive pole of the cell. Gases created on discharge are ordinarily emitted through the porous carbon rod electrode. An air space is provided above the depolarizer to accommodate any excess gas until

it can pass off through the carbon electrode. The absorbing material and depolarizer are saturated with a solution of sal ammoniac and zinc chloride which acts as the electrolyte to accomplish the necessary chemical action. The dry cell is used to best advantage where the requirements are for a low or intermittent current. It cannot be recharged. Cells not in use should be stored in a cool, dry place to prevent rapid deterioration. A new dry cell has a pressure of about 1.5 volts. A maximum current output of 20 to 35 amperes is obtained by a short circuit test (fig. 10).

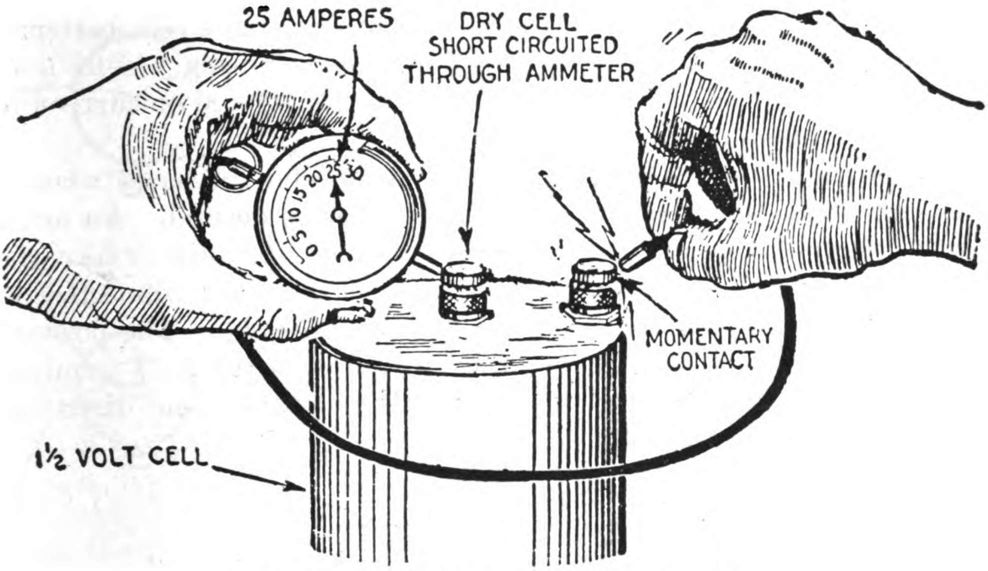



FIGURE 10.—Short circuit test of a dry cell.

(2) *Storage cell.*—(*a*) The storage cell used on the motor vehicle is a lead-acid cell. (See sec. III.) It consists of two sets of lead plates, known as positive and negative, placed in an acid-proof jar containing a solution of sulphuric acid and water. The cell is charged by electrochemical change when a direct current is passed through it from the positive terminal to the negative terminal. When the battery is used as a source of current, the chemical change is reversed and the cell becomes discharged. A single lead-acid cell gives a pressure of about 2 volts when fully charged. Several hundred amperes output can be obtained for short periods of operation.

(*b*) The nickel-iron-alkaline cell, known as the Edison cell, is another type of storage cell used mainly for large batteries on electrically-driven vehicles. It consists of nickel and iron plates contained in an alkaline solution. A single Edison cell gives a pressure of about 1.5 volts when fully charged and an output of several hun-

dred amperes for short periods of operation. The Edison cell is not used on the motor vehicle because of its low efficiency and high initial cost.

*b.* The generator is used in combination with the storage battery in the modern motor vehicle to keep the battery charged. The generator is discussed in section VI.

*c.* Ignition systems utilizing the magneto as the current source have been used extensively on automobiles, trucks, tractors, and aircraft. The different types of magnetos are discussed in section V.

**18. Series and parallel battery circuits.**—In order to obtain a larger source of energy than is possible with a single cell, batteries are usually composed of several cells acting in unison. Cells may be connected in series or in parallel to raise the voltage or current to the desired amount.

*a. Series operation.*—Battery cells are connected in series when a voltage greater than that produced by one cell is desired. An automotive electrical system is usually designed for 6 volts. Since the single storage cell gives only 2 volts, three cells are connected in series (fig. 11) to give the desired potential of 6 volts. The positive (+) terminal of one cell is connected to the negative (−) terminal of the next so that the cell voltages, acting in the same direction, are added.

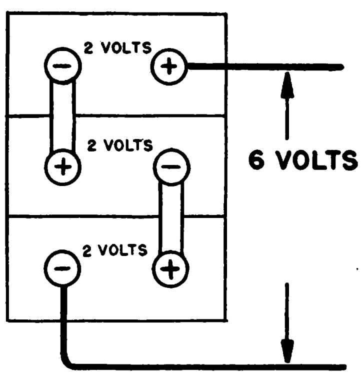



FIGURE 11.—Cell connections for a 6-volt storage battery.

Since the current is the same through all of the cells in the series, series connection does not increase the value of the current available. The voltage obtained by series connection is the sum of the voltages of the individual units and the current obtained is the average current of the individual units.

*b. Parallel operation.*—Battery cells are connected in parallel when a current larger than that available from one cell is desired. The connections and results obtained by parallel connection are the reverse of those obtained by series connection. Opposite terminals are con-

nected in series operation while like terminals are connected in parallel operation. The comparison of series and parallel connections is shown in figures 12 and 13. The current obtained by parallel connection is the sum of the currents of the individual units, and the voltage obtained is the average voltage of the individual units.

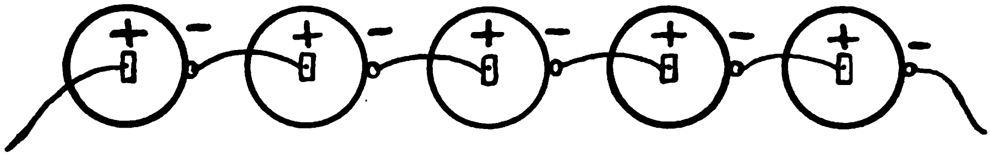


FIGURE 12.—Five dry cells connected in series.

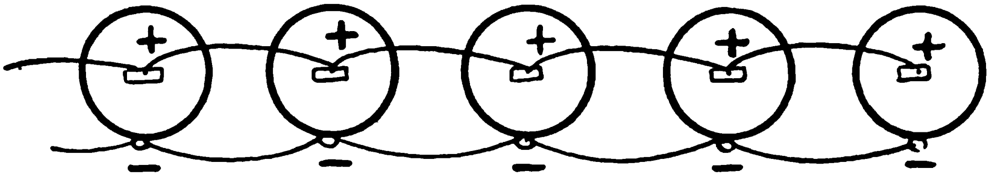


FIGURE 13.—Five dry cells connected in parallel.

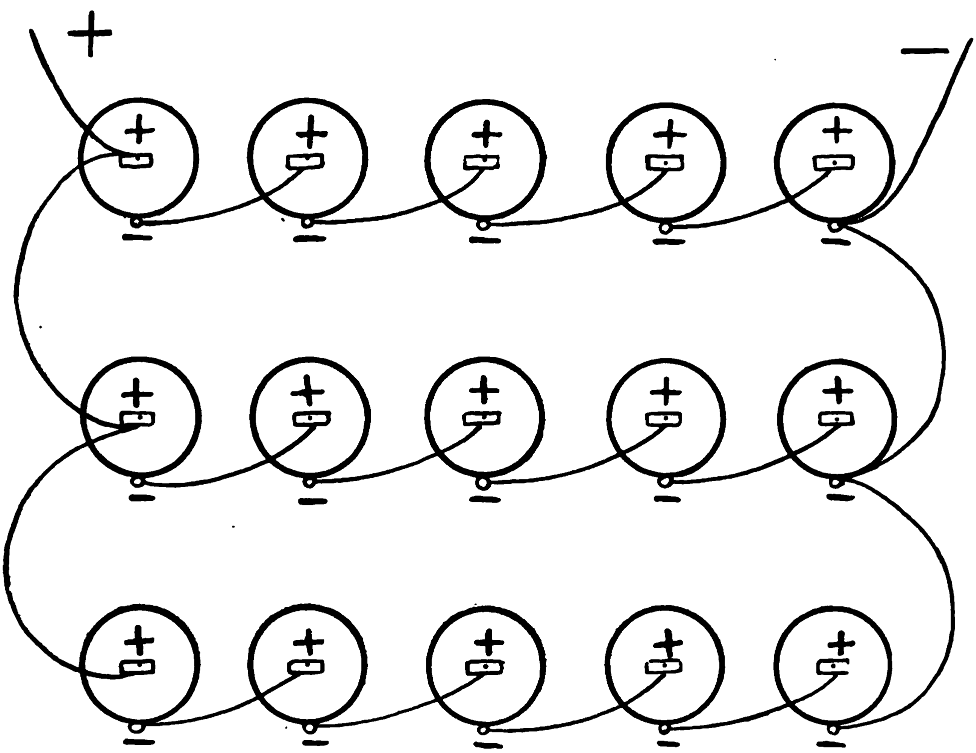


FIGURE 14.—Fifteen dry cells connected in a series-parallel circuit.

*c. Series-parallel operation.*—When a large current is required at a voltage above that of a single cell, the series-parellel connection is used. This arrangement consists of a parallel connection of banks of cells in series. An arrangement of three parallel banks, each having five cells connected in series, is shown in figure 14. The total voltage of

each bank is the sum of the voltages of the individual cells, while the current through each series bank is the average current of the individual cells in the bank. The currents from each of the banks in parallel add together while the total voltage of the series-parallel connection is the average voltage of the individual banks. Taking 20 amperes and 1.5 volts as the output of each cell, this arrangement would give $20\times3=60$ amperes at a potential of $1.5\times5=7.5$ volts.

**19. Magnetism.**—Magnetism is a property of certain materials that enables them to attract and repel iron (serving as a reference material). It is closely allied to electricity although it is of an entirely different nature. Like electricity, little is known of magnetism, but its properties and the rules governing its actions are well established.

*a. Magnetic and nonmagnetic materials.*—Iron and steel and some alloys containing iron are the only common materials which exhibit marked magnetic properties. Nickel and cobalt are appreciably affected by magnetism. Materials such as copper, aluminum, or zinc, which are not susceptible to magnetism, are known as nonmagnetic materials.

*b. Magnets.*—The name "magnet" was originally applied to the lodestone (leading stone), an iron oxide mineral which long ago was found to point to the earth's North Pole. This natural magnet (the only one known) imparts its magnetic property to pieces of iron and steel which are stroked by it. Such pieces of iron or steel are said to be magnetized and are called artificial magnets. For commercial purposes, artificial magnets are magnetized by an electric current. (See pars. 22 and 23.) Magnets produced by artificial means are said to have been magnetized by induction. Magnetic induction takes place through all nonmagnetic materials whether they are solids, liquids, or gases. In other words, nonmagnetic materials are not magnetic insulators.

*c. Temporary and permanent magnets.*—Soft iron, because it loses its magnetism readily after the magnetizing force is removed, is called a temporary magnet. A bar of hardened steel once magnetized will, with proper treatment, remain so almost indefinitely and is called a permanent magnet. Cores of induction coils, which require strong magnetism only when current is flowing in the coil, are made of soft iron, usually a bundle of soft iron wires. Magnets of a magneto, which require permanent magnetic properties to start the generation of current, are made of hardened steel or special magnetic alloys.

**20. Poles of a magnet.**—*a.* The strength of a magnet, or its power of attracting iron, is concentrated at certain points called the poles. In a bar magnet, the strength is greatest at the ends, consequently the ends form the poles. The pole which always points to the earth's North Pole, when the magnet is suspended freely, is called the north-seeking or simply the north (N) pole of the magnet. The other pole of the magnet is called the south (S) pole.

*b.* When two magnets are brought together, it is found that the north pole of one attracts the south pole of the other and that two like poles, either north and north or south and south, repel each other. (See fig. 15.)

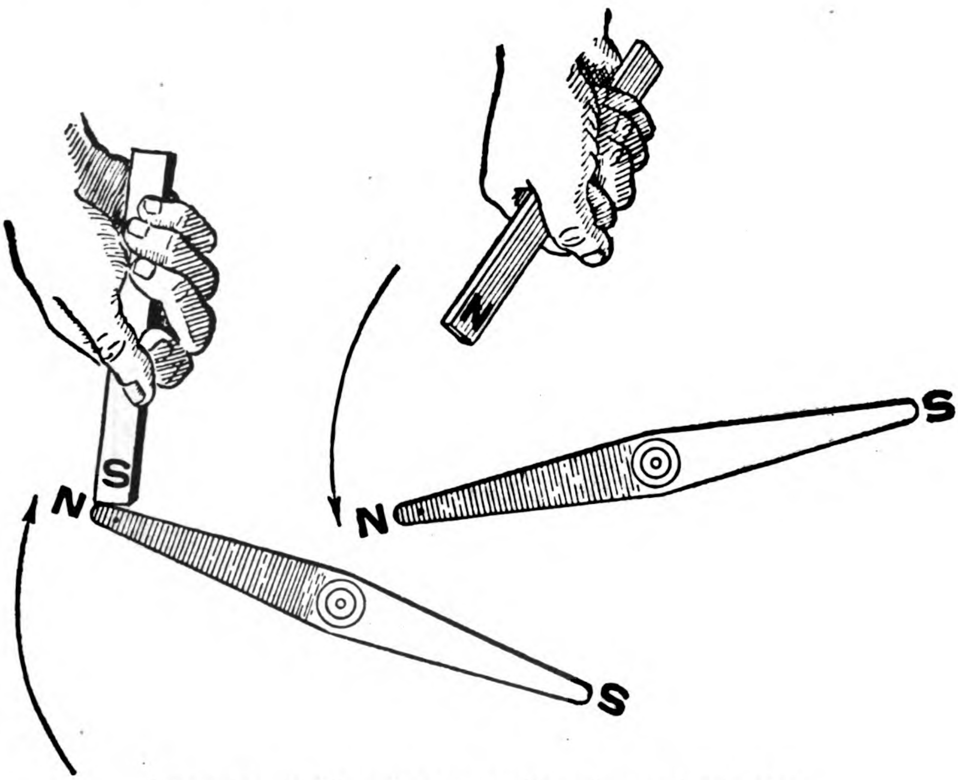



FIGURE 15.—Unlike poles attract, like poles repel each other.

*c.* The polarity of a magnet can be readily determined by a compass as shown in figure 16. The north end of the compass needle will always point toward the south pole of the magnet. Likewise, the south end of the compass needle will point toward the north pole of the magnet.

**21. The magnetic field.**—*a.* It is generally believed that magnetism acts in the nature of a stream or current. This flow of magnetism is termed "magnetic flux" and is conventionally represented

by lines of force which always flow out of the north pole of a magnet and around into the south pole, forming a complete circuit. This action may be seen readily by placing a piece of paper over a bar

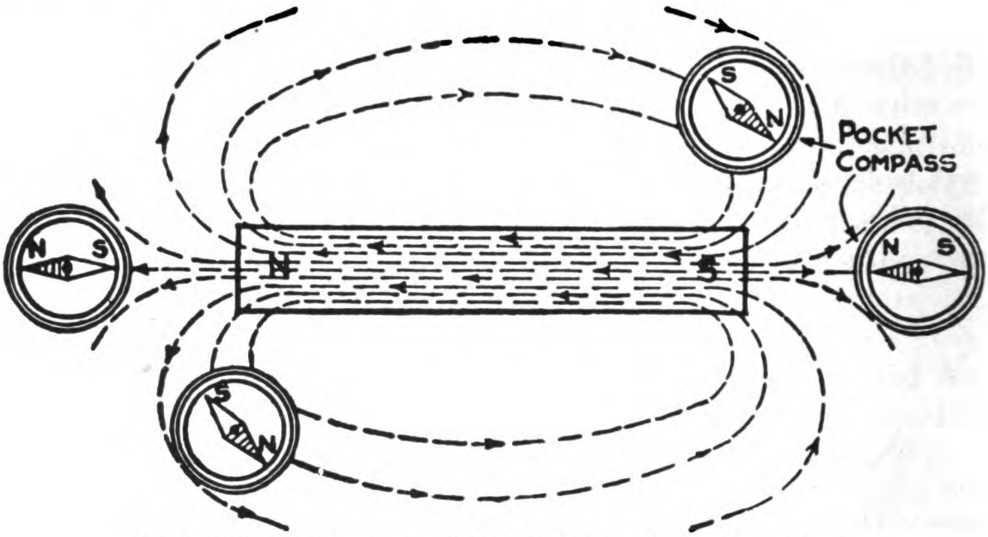



FIGURE 16.—Using a compass to determine polarity of a magnet.

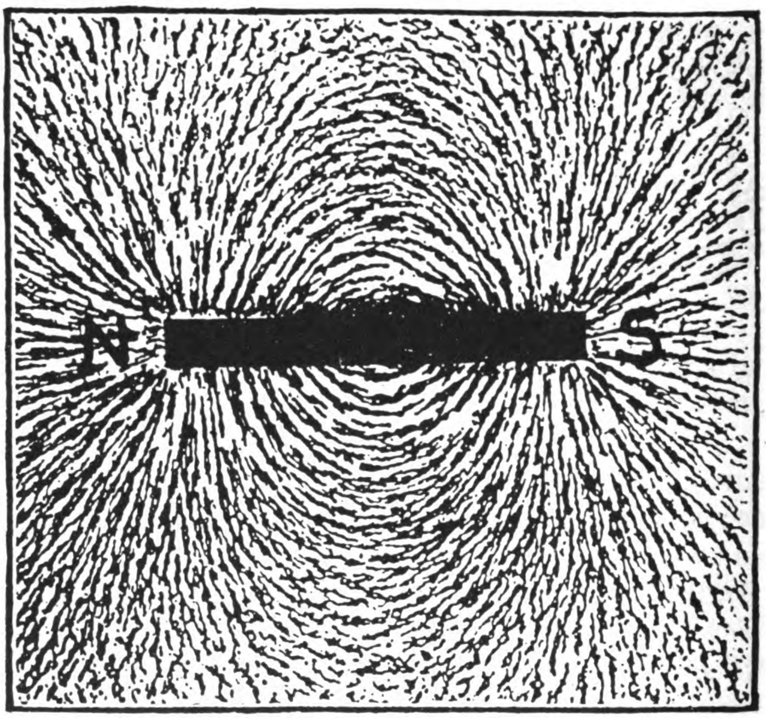
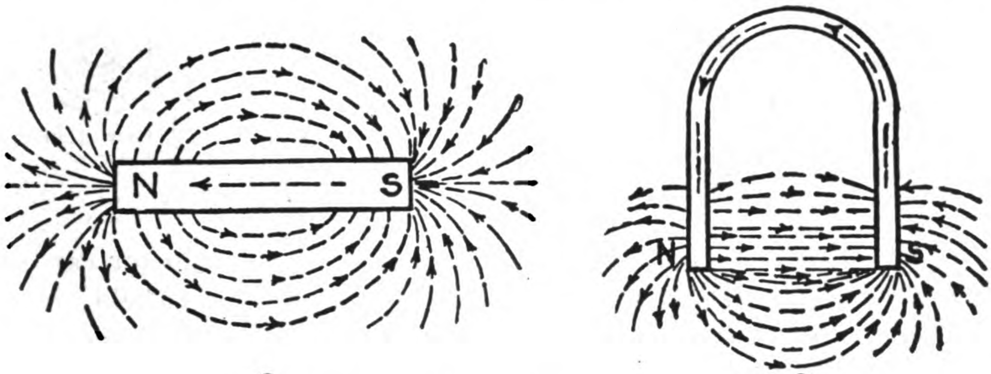



FIGURE 17.—Magnetic field of a magnet shown by iron filings.

magnet and sprinkling iron filings over the paper. The magnetic force will arrange the filings in lines running from one end of the magnet around to the other end as shown in figure 17. The conventional

method of representing the magnetic field around a bar magnet and a horseshoe magnet is shown in figure 18.

*b.* The region surrounding a magnet through which the magnetism flows from the north pole to the south pole is known as its magnetic field. The strength of this field depends upon the pounds pull per unit

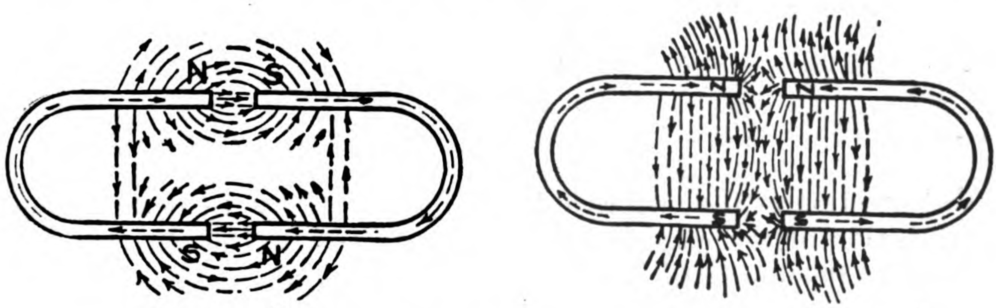



① ②

FIGURE 18.—Magnetic field around bar and horseshoe magnets.

area of the pole and is usually measured by a certain number of magnetic lines of force per square inch.

*c.* When like and unlike poles are brought close together, the resulting magnetic fields look like those shown in figure 19. Figure 19 ①,



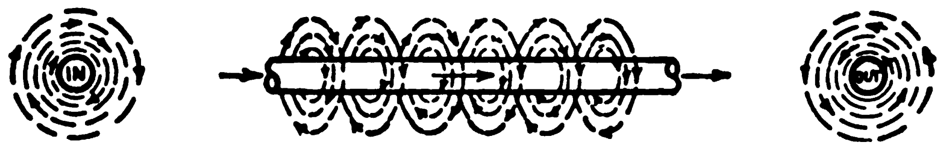
① ②

FIGURE 19.—Magnetic fields between like poles (right) and unlike poles (left).

showing unlike poles together, gives the impression of a continuous flow because the two fields are oriented in the same direction. The action in figure 19 ②, showing like poles together, which can be compared to two jets of water directed against each other, is the result of bringing two opposing magnetic fields together.

**22. Electromagnetism.**—*a.* Magnetism produced by an electric current is called "electromagnetism." Experiments show that a wire or any other conductor carrying an electric current will have a magnetic field set up around it proportional in strength to the amount of current it carries. This fact constitutes the basis for the relation be-

tween electricity and magnetism. The magnetic field thus produced is arranged in concentric circles around the wire (fig. 20) and flows clockwise when looking along the wire in the direction the current is flowing.




① Left end view (current going in). ② Side view (current flowing from left to right). ③ Right end view (current going out).

FIGURE 20.—Magnetic field surrounding an electrical conductor.

*b.* The direction of the magnetic field around a conductor can be determined by a pocket compass. The magnetic needle, if held above or below a wire carrying a direct current, will turn across the wire (fig. 21) with the north end of the compass pointing around the wire

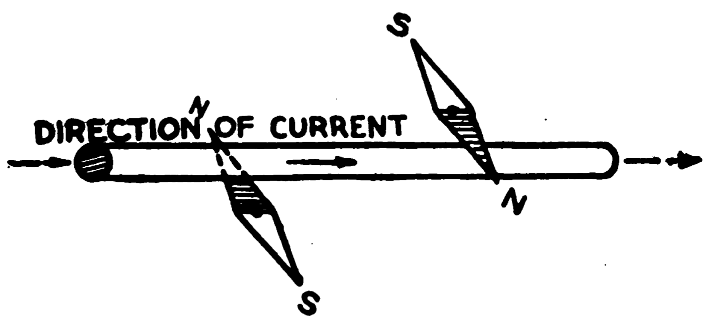



FIGURE 21.—Using a compass to determine in which direction the current is flowing.

in the direction of the magnetic lines of force. Thus, by determining the direction of the magnetic field around the wire, the direction of the current flowing in the wire may also be determined.

*c. Solenoid.*—If the wire is coiled into a loop, it will be found that the concentric lines of force go in the same direction through the center of the loop (fig. 22). If two loops are placed close together, the lines of force will merge and go around the two wires together (fig. 23).

If a number of turns of insulated wire are wound into a coil or solenoid (fig. 24), nearly all the lines of force will enter one end of the coil, pass through it, leave the opposite end, and return outside the coil to complete the circuit. Thus, a solenoid or coil carrying an electric current has the same character of magnetic field as a bar magnet. It has a north pole where the lines of force leave the coil and a south pole where the lines of force enter the coil.

**23. The electromagnet.**—*a. Permeability.*—Permeability is the ability of a material to conduct magnetism. It is expressed as the ratio of the strength of a magnetic field with a given material forming its entire core, to the strength of the field if air is used as the core. Nonmagnetic substances all have a permeability of 1. All

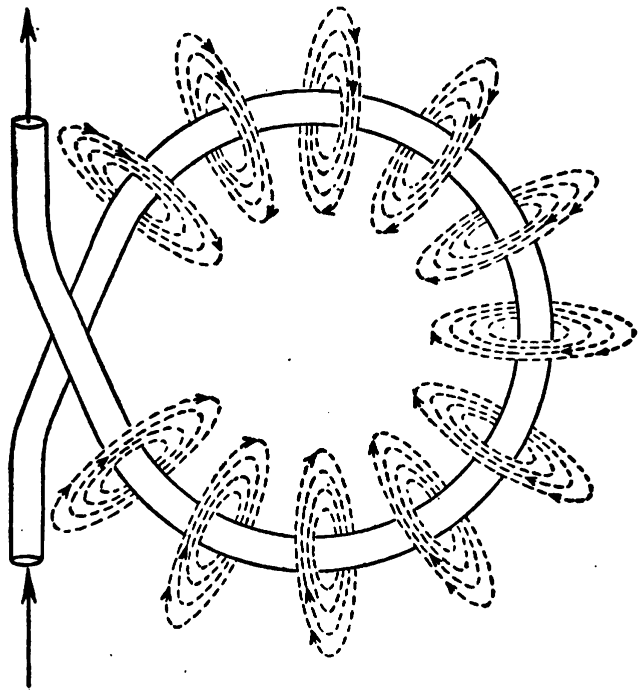


FIGURE 22.—The magnetic field produced by current flowing in a single loop of wire.

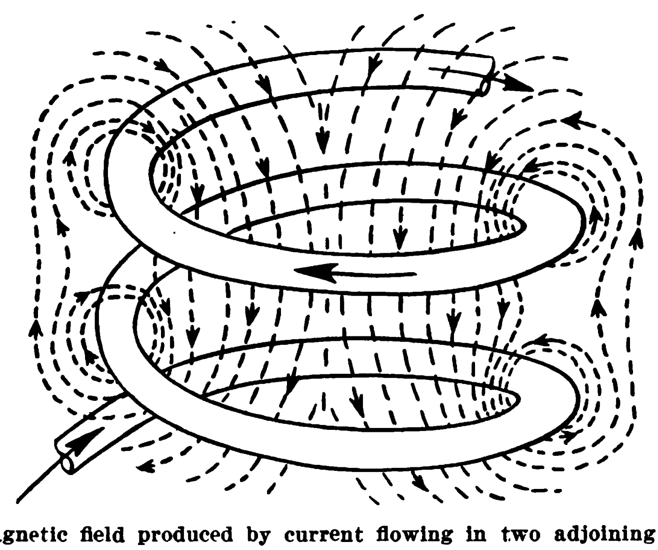


FIGURE 23.—Magnetic field produced by current flowing in two adjoining loops of wire.

magnetic substances have permeabilities much greater than 1, the value depending upon the character of the substance and the magnetizing force. The strength of an electromagnet varies with the

material used for the core. An electromagnet with air for a core (fig. 24) is not very strong, but may be made so by inserting soft iron for the core because iron is a much better conductor of magnetism than air. Wrought iron, which is very soft, reaches a permeability of 3,000 .

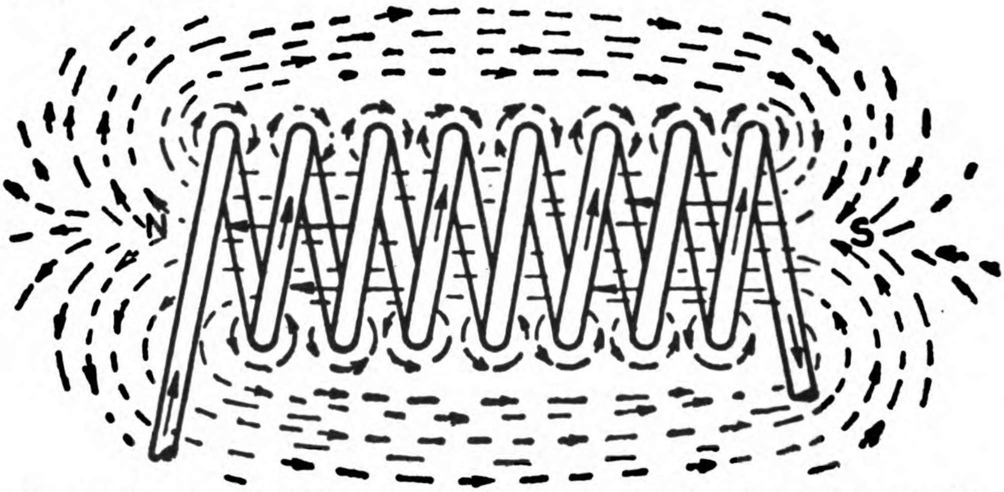
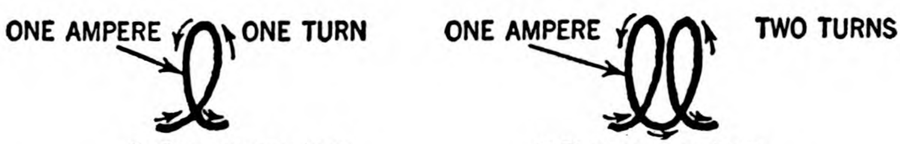
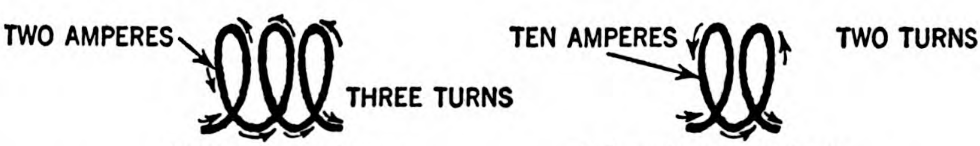



FIGURE 24.—Magnetic field produced by current flowing through a coil or solenoid.

*b. Ampere turns.*—The strength of an electromagnet may also be increased by increasing the magnetizing force which depends upon the amount of current flowing through the winding and the number of turns in the coil. In fact, the magnetic pull of the electromagnet core will depend not only on the size, length, and material of the core but also on the number of amperes multiplied by the number of turns in the winding, or the total number of ampere turns producing the magnetism (fig. 25).




① One ampere turn. ② Two ampere turns.




③ Six ampere turns. ④ Twenty ampere turns.

FIGURE 25.—Magnetizing force of a coil depends upon amperes and number of turns in the coil.

*c. Saturation.*—Magnetic materials tend to become magnetically saturated when conducting considerable magnetism; that is, magnetic materials can pass only a certain amount of magnetic flux just as

electrical conductors can pass only a certain amount of current. When the magnetizing force is such that the magnetic material is saturated with magnetism (reached the saturation point), additional magnetizing force will not produce much increase in magnetic field strength.

*d. Polarity.*—(1) A simple method for determining the polarity of an electromagnet, if the direction of current is known, is to grasp the coil in the right hand with the fingers pointing around the coil in the same direction as the current. With the hand in this position (fig. 26), the thumb will point in the direction of the magnetic lines of force or along the core to the north pole.

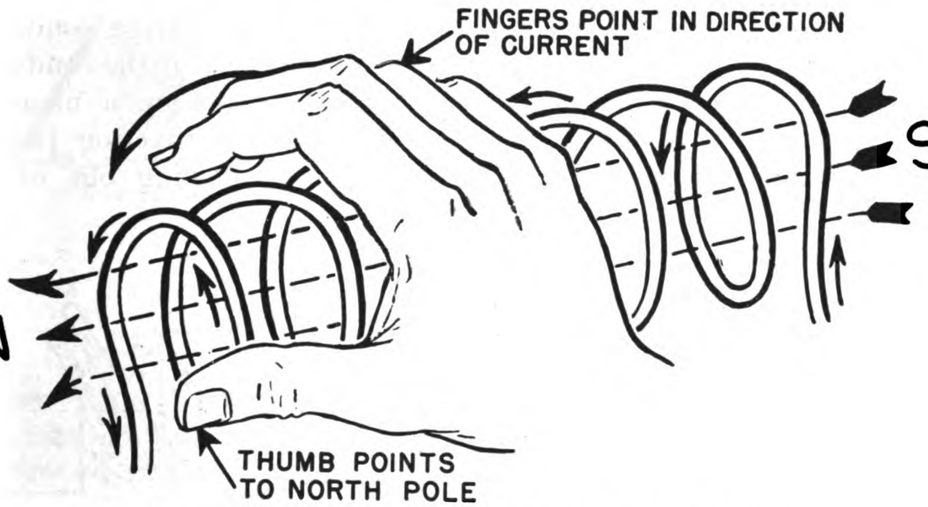



FIGURE 26.—Determining polarity of an electromagnet.

(2) The polarity of an electromagnet may also be quickly determined by holding a compass near its poles. The north end of the needle will point to the south pole of the electromagnet.

**24. Electromagnetic induction.**—Since it is true that a current flowing in a conductor produces a magnetic field around the conductor, it is also true that setting up a magnetic field around a conductor produces an electric current when the conductor is in a closed circuit.

*a. Induced current.*—The process of generating a current in this manner is known as induction, and the current thus produced is called an induced current. If the current is generated by magnetism alternating in direction with respect to the conductor, the induced current will also be alternating in direction with as many reversals per second through the wire as there are reversals of magnetism around it. Such a current is called alternating current and is usually abbreviated a. c.

(1) A magnetic field may be set up to induce current in a wire by two methods: either by cutting a magnetic field with a wire, as is done in a stationary field type magneto or a generator; or by cutting the wire with a moving magnetic field, as in the inductor type magneto and in the induction coil.

(2) The method by which a magnetic field is set up around a conductor and the relative direction of the induced current are shown in figure 27. *N* and *S* represent the north and south poles of a magnet and *W* a wire cutting through a magnetic field between *N* and *S* in a downward direction. The magnetic lines of force between *N* and *S* tend to act like rubber bands under tension, becoming distorted by the moving wire (fig. 27 ②). It may be noted that the distorted lines of force crowding ahead of the moving conductor or wire create a field of greater intensity on one side of the conductor than on the other. This has the effect of setting up a magnetic whirl around the conductor in a counterclockwise direction (fig. 27 ③), thereby inducing a voltage and current flowing out of the conductor as indicated.

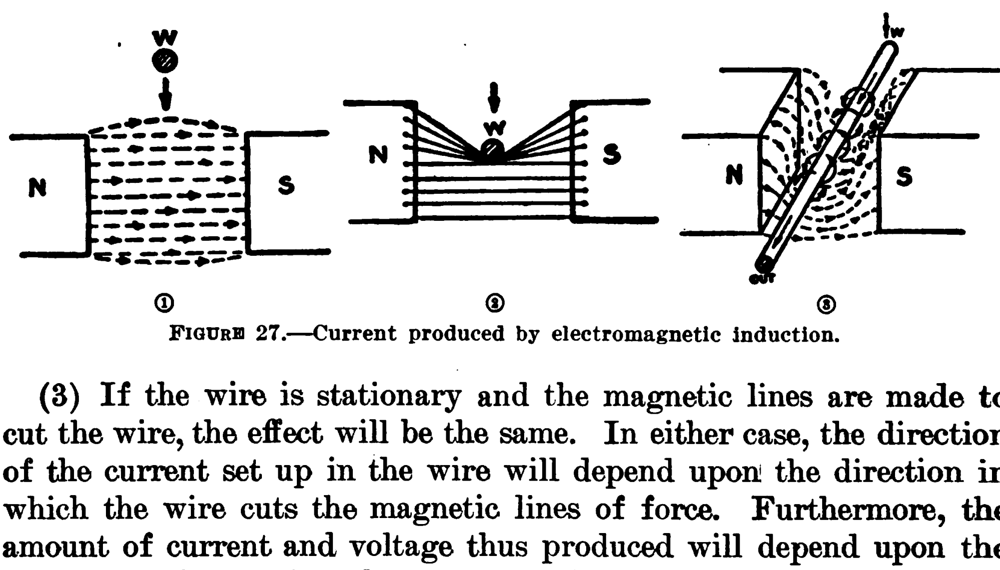



FIGURE 27.—Current produced by electromagnetic induction.

(3) If the wire is stationary and the magnetic lines are made to cut the wire, the effect will be the same. In either case, the direction of the current set up in the wire will depend upon the direction in which the wire cuts the magnetic lines of force. Furthermore, the amount of current and voltage thus produced will depend upon the resistance of the wire, the strength of the magnetic field, and the speed at which the magnetic lines of force are cut.

*b. The right hand rule.*—An easy method for determining the relation between the induced current, the direction of magnetism, and the motion of the wire through the magnetic field is to hold the right hand with the thumb and first two fingers at right angles to each other. If the first finger is pointed in the direction of the

magnetic field from *N* to *S*, (fig. 28) and the thumb in the direction of motion of the conductor with respect to the field, the second finger will point in the direction of the induced current.

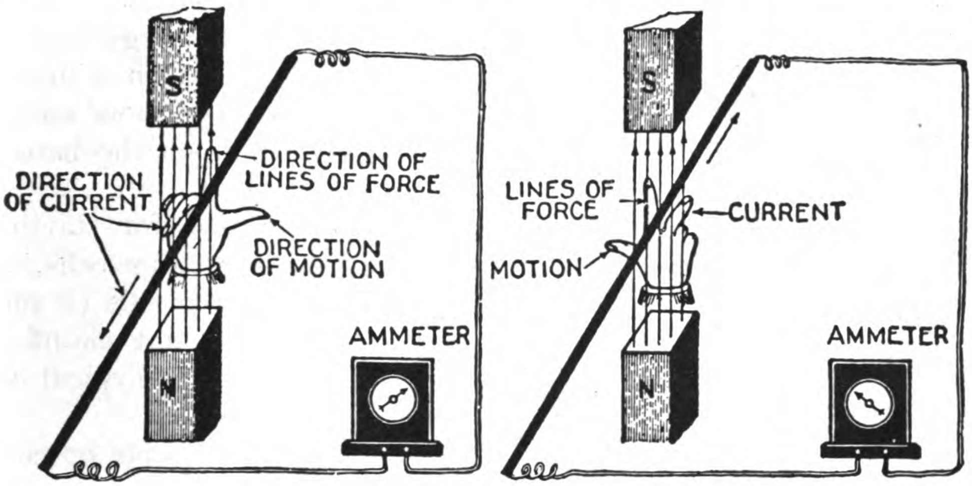



FIGURE 28.—Determining direction of induced current (right hand rule).

## SECTION III

## THE STORAGE BATTERY



**25. General.**—*a.* The storage battery provides electrical energy through a chemical reaction. When a generator in a motor vehicle's electrical system produces more electrical energy than required for ignition and for operating electrical accessories, the surplus passes through the battery to reverse the chemical reaction. This is known as charging the battery. When the generator is not producing the necessary electrical energy, the battery through chemical reaction, can supply the energy required in the electrical system of the vehicle. The battery is then said to be discharging.

*b.* In any system of storage, if more is taken out than is put back, the reservoir ultimately becomes empty. Comparing the motor vehicle's electrical system to a water storage system (fig. 29) will explain why a storage battery runs down or becomes discharged.

If more water is taken from the outlets than can be pumped into the tank, the tank eventually runs dry. Similarly, if the energy used by the starter, lights, horns, etc., exceeds the energy input from the generator, the battery eventually becomes discharged or loses its energy. If the engine is not in good order, more energy may be required for starting than the generator can put back in a limited time. Electrical accessories that continuously require more energy than the generator can provide are a steady drain on the battery and will discharge it.

**26. Construction.**—The storage battery, as used for starting, lighting, and ignition purposes, consists of three or more cells, depending upon the voltage desired. A battery of three cells (2 volts each) connected in series is known as a 6-volt battery and one of six cells connected in series is known as a 12-volt battery. Typical cell construction is shown in figure 30.

*a. Plates.*—(1) Each cell consists of a hard rubber jar or compartment into which are placed two kinds of lead plates, known as positive and negative. These plates are insulated from each other by suitable separators and are submerged in a solution of sulphuric acid and water.

(2) The backbone of both the positive and negative plates is a grid made of a stiff lead alloy casting. The grid, usually composed of vertical and horizontal cross members, is carefully designed to give the plates mechanical strength and at the same time to provide adequate conductivity for the electric current created by the chemical action. The active material of the plates is applied to the grids in paste form. Part of a grid is shown in figure 31, with a cross section to show the active material in place. The active material, composed chiefly of oxides of lead, is allowed to dry and harden like cement after being applied to the grid. The plates are then put through an electrochemical process that converts the hardened active material of the positive plates into brown peroxide of lead, and that of the negative plates into gray, spongy, metallic lead. Plates that have been put through this process, known as forming the plates, are shown in figure 32 ① and ②.

*b. Groups.*—After the plates have been formed, they are built into positive and negative groups. The plates of each group are permanently joined by melting a portion of the lug on each plate to form a solid weld with a connecting post strap. The heat necessary for this process, termed "lead burning", is produced by a gas flame or an electric arc. The connecting post strap to which the plate lugs are burned contains a cylindrical terminal which forms the outside con-

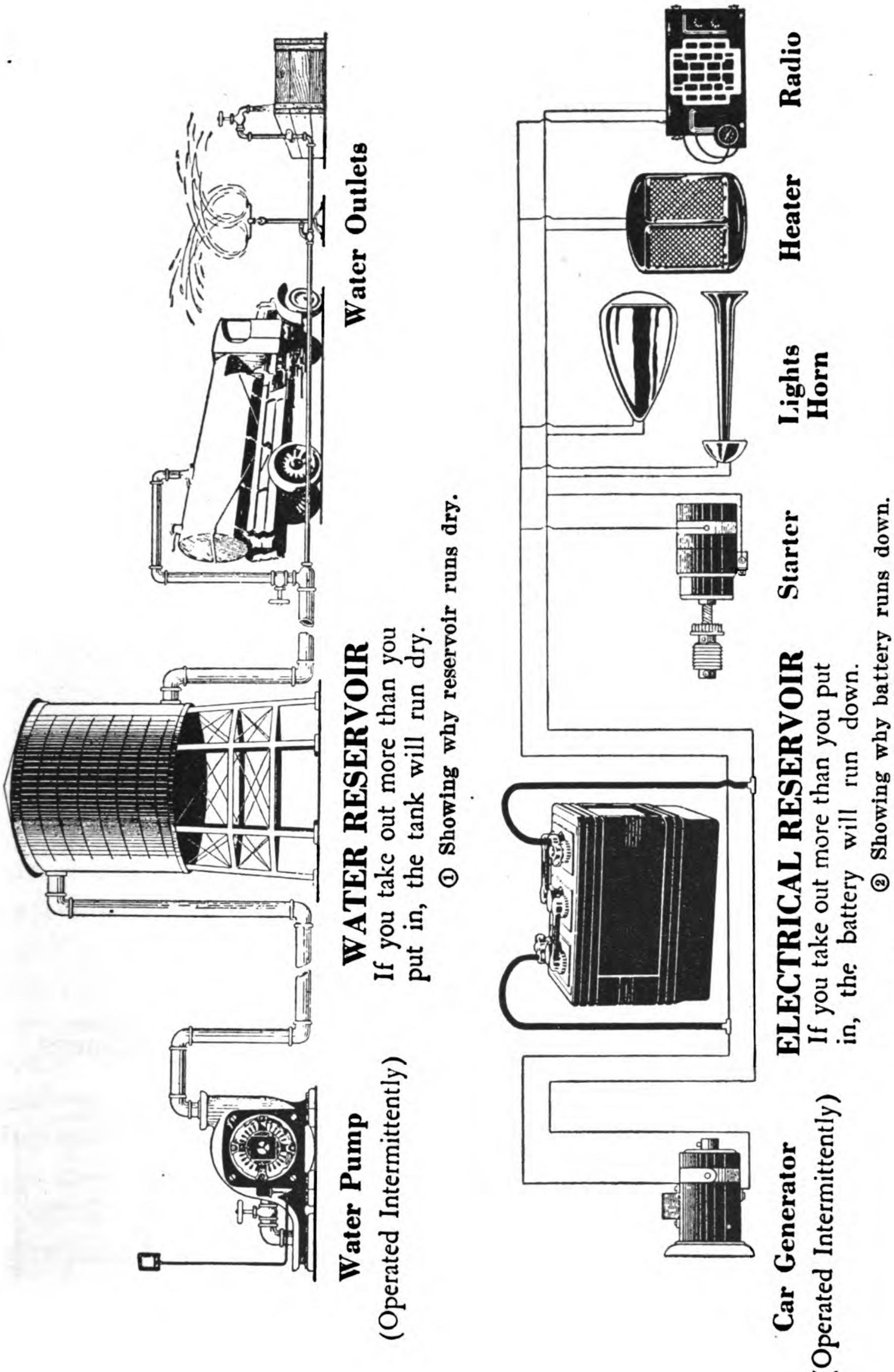



FIGURE 29.—Comparison of storage battery and water reservoir.

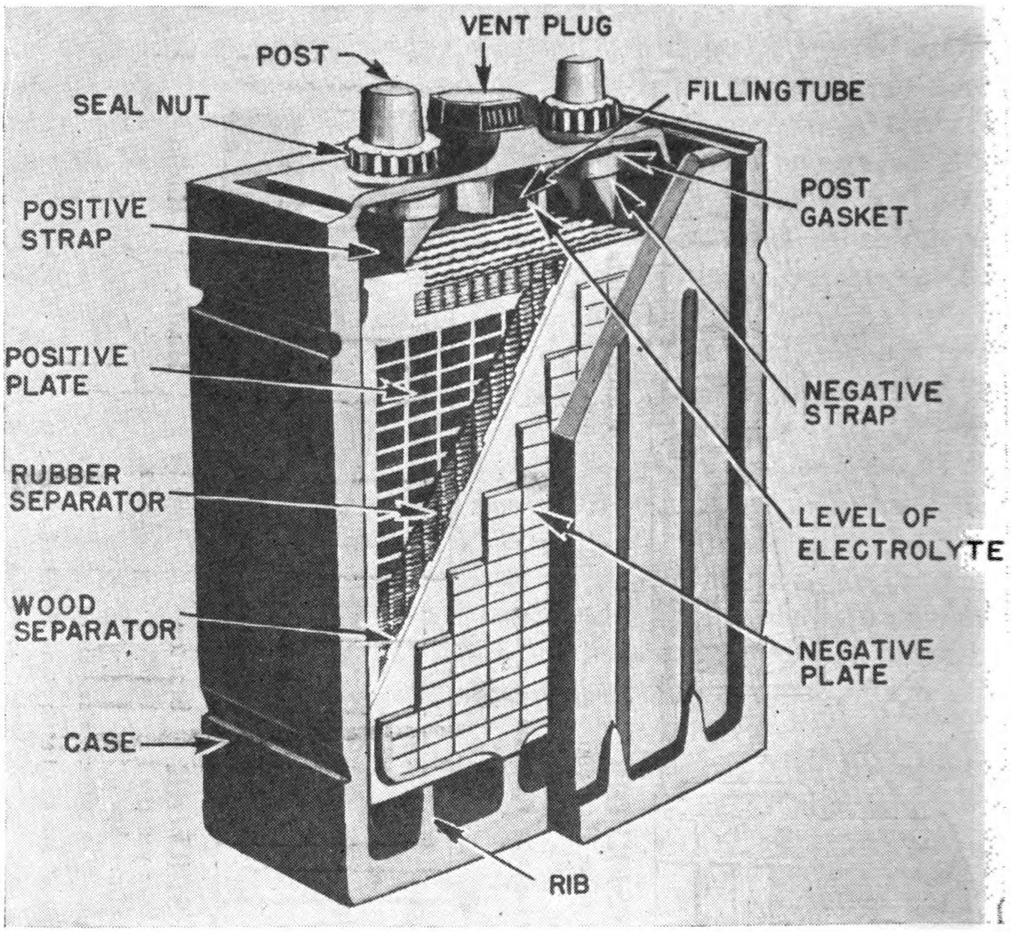



FIGURE 30.—Sectional view of storage battery.

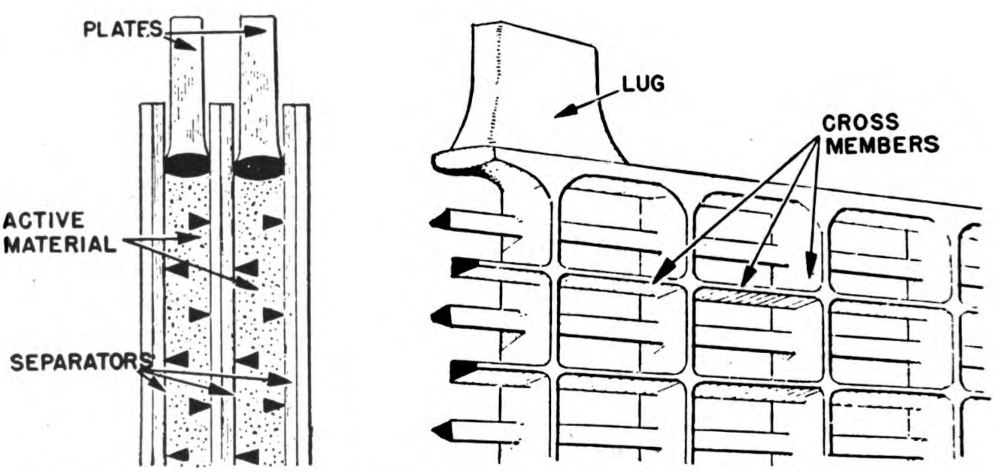



FIGURE 31.—Section of a battery plate grid with cross section showing active material in place.

nection for the cell. The negative group of plates has one more plate than the positive group to provide a negative plate on both sides of all positive plates. These groups are shown in figure 32 ⑤ and ⑥.

*c. Elements.*—The assembly of a positive and negative group, together with the separators, is called an element. Since storage battery plates are more or less of standard size, the number of plates in an element is roughly a measure of the battery capacity. The distance between the plates of an assembled element is approximately ⅛ inch.

*d. Separators.*—To prevent the plates from touching and causing a short circuit, sheets of insulating material (usually wood or porous rubber) called separators are inserted between the plates. These separators (fig. 32 ③ and ④) are thin and porous so the electrolyte will flow easily between the plates. Separators made from spun glass have recently been developed which are said to be very effective. One side of the separator (that placed against the positive plate) is grooved so the gas that forms during charging will rise to the surface more readily. These grooves also provide room for any active material that flakes from the plates to drop to the sediment space below.

*e. Electrolyte.*—An electrolyte is a liquid which readily conducts electricity and is decomposed when an electric current passes through it. The electrolyte in the lead-acid storage battery, having a specific gravity of 1.280, is composed of one part of chemically pure sulphuric acid ($H_2SO_4$) and approximately two and three-fourths parts by volume of distilled pure water. A small quantity of some impurity introduced into the acid solution by using impure water might interfere with the chemical action and cause battery trouble.

*f. Container.*—(1) A battery container is a receptacle for the cells that make up the battery. It is made of hard rubber or a composition material which is resistant to acid and mechanical shock. Most motor vehicle batteries are assembled in a one-piece container with three or six compartments for the individual cells. (See fig. 33.) One element and enough electrolyte to cover the plates are inserted into each cell compartment of the container.

(2) Stiff ridges or ribs molded in the bottom of the container form a support for the plates and a sediment recess for the flakes of active material which drop off the plates during the life of the battery. The sediment is thus kept clear of the plates so that it will not cause a short circuit across the bottom of them.

*g. Cover.*—A hard rubber cover, provided with openings for the two terminals of the element and for a vent plug, is placed on each

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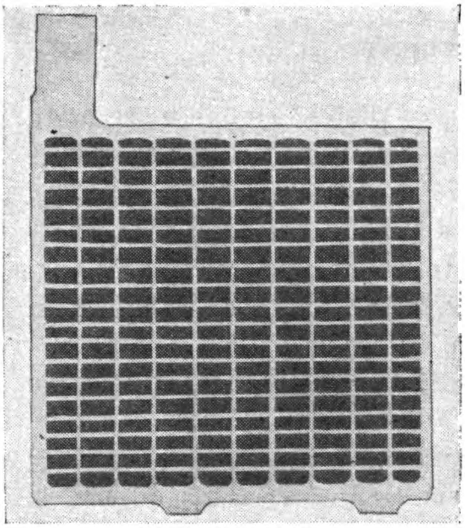
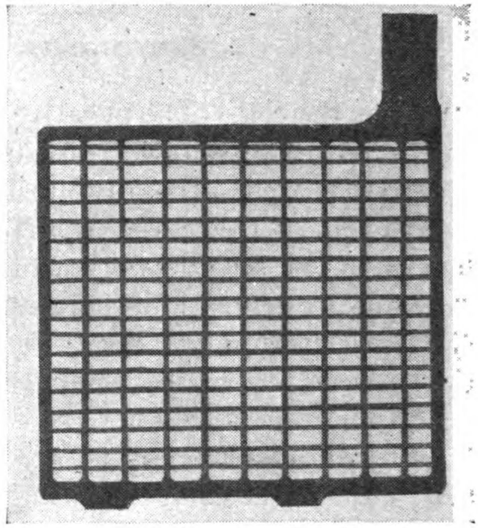
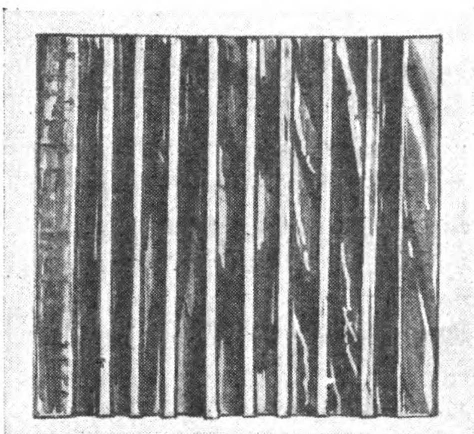


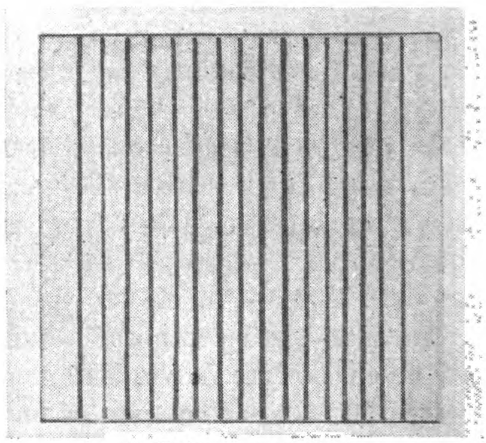
① Positive plate.



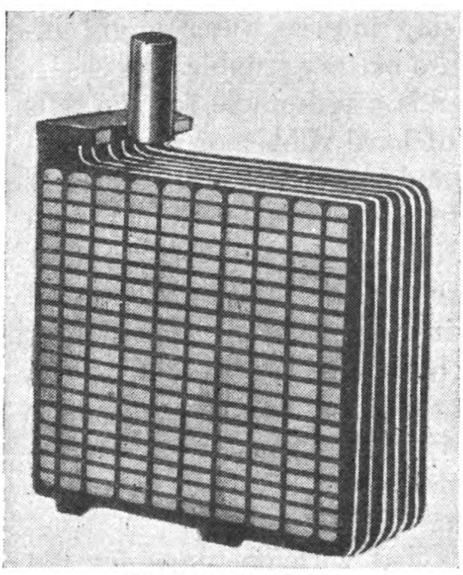
② Negative plate.



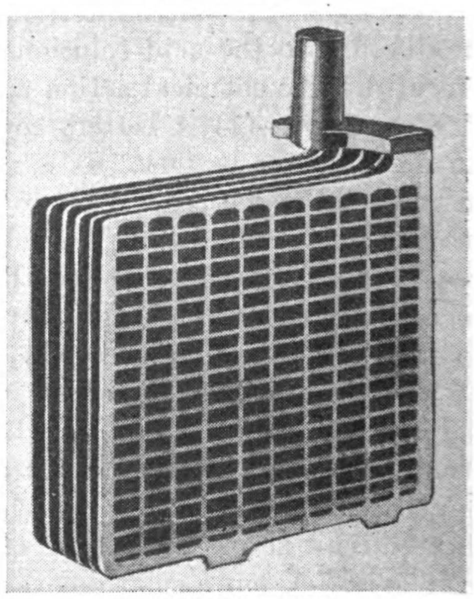
③ Wood separator.



④ Rubber separator.



⑤ Negative group.



⑥ Positive group.

FIGURE 32.—Storage battery plates and separators.

cell (fig. 34). The cells are then sealed with pitch and connected in series by burning cell connectors on the terminals. The vent plug allows accumulated gas to escape and prevents the electrolyte from splashing outside the battery. Checking and filling the battery can be done by unscrewing the vent plug.

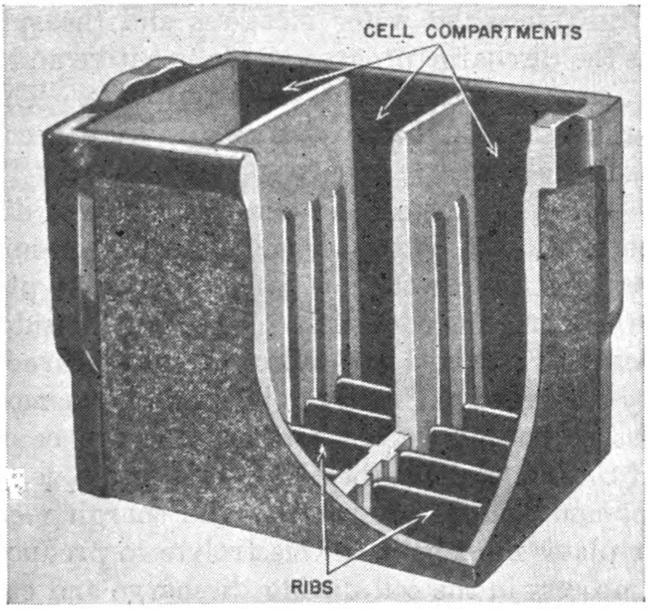



FIGURE 33.—A one-piece battery container having three cell compartments.

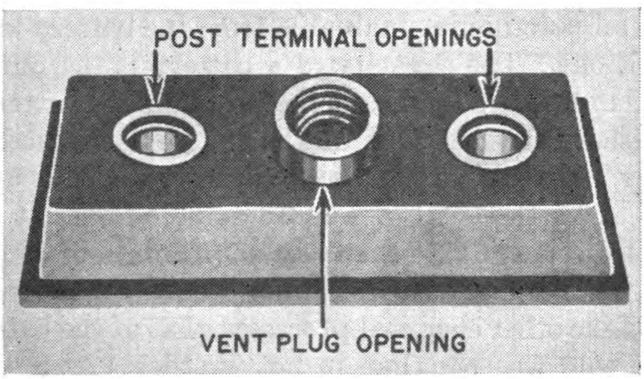



FIGURE 34.—Cover for a battery cell.

**27. Principle of operation.**—When a cell is fully charged, the negative plate is spongy lead, the positive plate is lead peroxide, and the electrolyte contains a maximum amount of sulphuric acid. Both the negative and positive plates are very porous and readily acted upon by the acid. A cell in this condition can produce electrical energy through reaction of the chemicals.

*a. Discharge.*—If the terminals of the battery are connected to a closed circuit, the cell discharges to supply electric current. The chemical process that occurs during discharge changes both the lead (Pb) of the negative plate and the lead peroxide ($PbO_2$) of the positive plate to lead sulphate ($PbSO_4$) and the sulphuric acid ($H_2SO_4$) to water ($H_2O$). Thus the electrolyte becomes weaker during discharge, since the water increases and the sulphuric acid decreases. As the discharge progresses, the negative and the positive plates finally contain considerable lead sulphate. The discharge should always be stopped before the plates have become entirely changed to lead sulphate.

*b. Charge.*—To charge the cell, an external source of direct current must be connected to the battery terminals. The chemical reaction is then reversed and returns the positive and negative plates and the electrolyte to their original condition. When all the sulphate ($SO_4$) on the plates has been returned to the electrolyte to form acid ($H_2SO_4$), the cell is fully recharged and ready to be used for the next discharge. Charging must be started before both plates have become entirely sulphated. If this is not done, the plate surfaces are no longer chemically different and will not respond to the charging current since two dissimilar plates must be in the electrolyte to produce the action. The chemical process in the cell during discharge and charge can be followed from figure 35.

*c. Capacity.*—All batteries are given a normal capacity rating according to the ampere-hours obtainable from the battery under certain working conditions. The capacity of a battery is the number of amperes delivered multiplied by the number of hours the battery is capable of delivering this current. One of the inherent characteristics of a storage battery is that its ampere-hour capacity depends upon the rate of discharge. A battery will give more ampere-hours at a long, low, or intermittent discharge rate than at a short, high, or continuous discharge rate. This is because the voltage drops relatively faster at higher rates. Like other chemical processes, that of the battery is much less efficient in cold weather than in hot weather. At 0° F. a battery has only about 50 percent of the full cranking capacity available at 80° F. In an emergency, little if any permanent harm will result if a battery is discharged at a very high rate, provided that it is promptly recharged. The battery is likely to deteriorate if left in a discharged condition.

**28. Charging.**—*a.* A storage battery should not have its cycle of operation interrupted. It should not be discharged and recharged at repeated short intervals. When its energy is exhausted, it should be

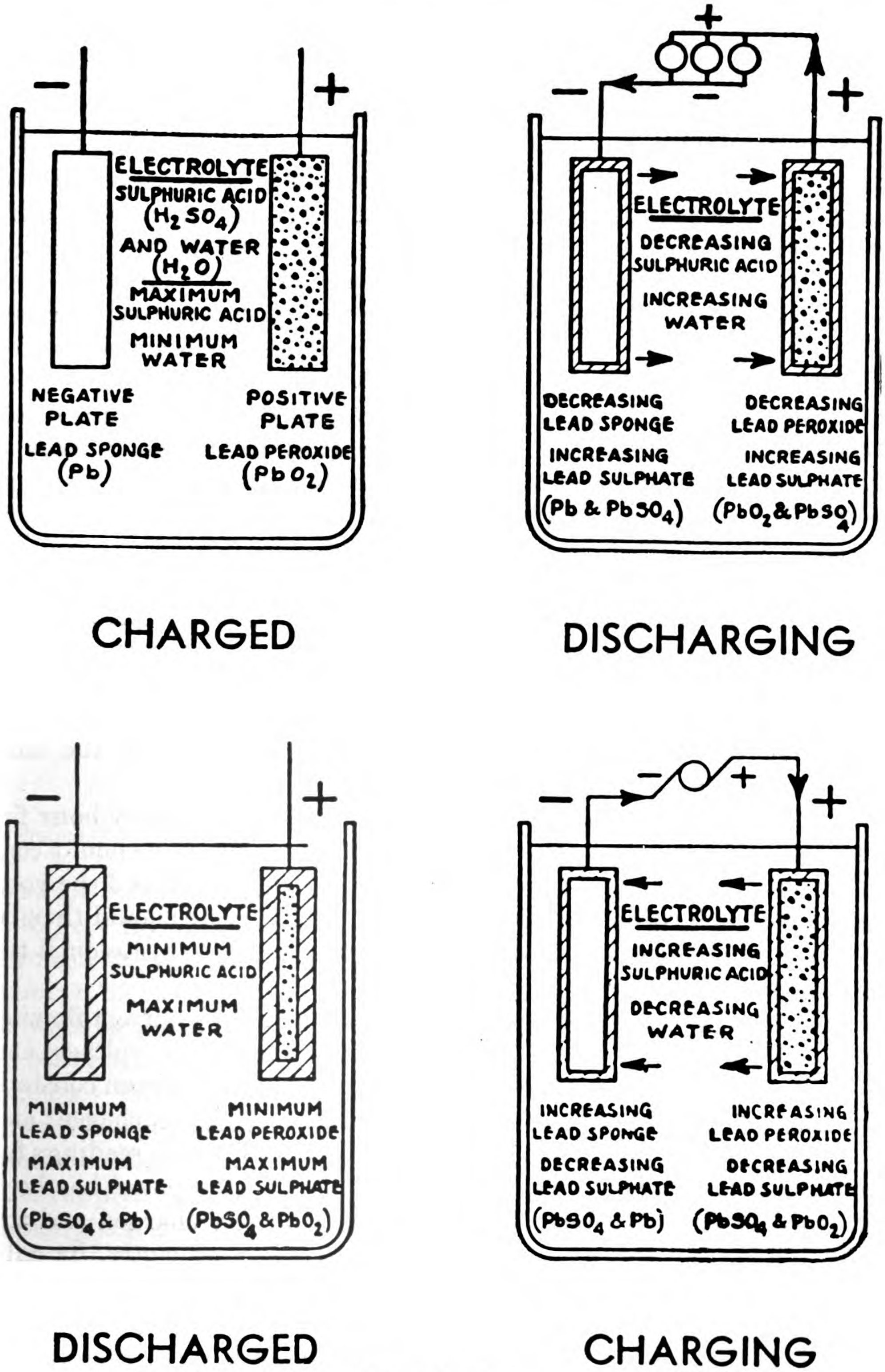



FIGURE 35.—Chemical action in a storage battery.

recharged immediately. Such desirable operation cannot be obtained in a motor vehicle because the battery is used intermittently. Hence, a battery is likely to run down, particularly in winter when starting demands are great, and require an outside source to renew its charge.

*b.* A storage battery can be charged by direct current only. If only alternating current is available, a motor-generator or rectifier must be used to convert it into direct current. In charging, the positive wire of the charging circuit must always be connected to the positive (+) terminal of the battery and the negative wire to the negative (−) terminal. The electrolyte in each cell should be brought to the proper level by the addition of pure water before the battery is connected for charging.

*c.* Batteries may be charged at any rate that does not raise the battery temperature above 110° F. When nearing full charge, it is better if the charging rate does not exceed 1 ampere (3/4 ampere is recommended) for each positive plate in a cell. A safe charging rate would be about 10 percent of the rated ampere-hour capacity at the beginning of the charge and 5 percent of this rating at the finish. A battery placed on charge should be carefully observed for several minutes to see whether it gases excessively, which indicates too high a charging rate. It is not recommended that a battery be charged at a very high rate unless properly controlled. If the rate exceeds 20 amperes, the battery should be carefully watched. Under no conditions should the temperature of the electrolyte be allowed to exceed 110° F.

*d.* Voltage and hydrometer readings should be made every hour for each cell when the battery is charging. The starting rate should continue until one or more of the cells are gassing vigorously and the voltage of each cell reads 2.4 or higher. The charging rate should then be reduced to the finish rate and charging continued at this rate until the battery is fully charged.

*e.* A battery is fully charged when, with the charging current flowing at the finish rate, all cells are gassing vigorously; the voltage and specific gravity of each cell have stopped rising and have been constant for 1 hour; the voltage reading is 2.4 or higher per cell on charge; and the specific gravity of each cell is between 1.270 and 1.285 (readings for electrolyte at 80° F.). When all the sulphate on the plates has been returned to the electrolyte, the element is completely charged and the charging current can do no more useful work; consequently, its only effect is to convert or decompose water in the electrolyte to hydrogen and oxygen gas which bubble violently. Care should be taken to keep open flames and burning cigarettes away from a battery which is or has been charging because the gas which accumulates in the cells is explosive.

**29. Charging methods.**—*a. Single battery charging (on 110-volt direct current).*—If a single 6-volt battery is to be charged from a 110-volt d. c. supply, a resistance must be placed in the circuit (in series) with the battery to regulate the amount of current. A very convenient resistance is a bank of 110-volt, 100-watt incandescent lamps connected in series with the battery (fig. 36). The lamps themselves

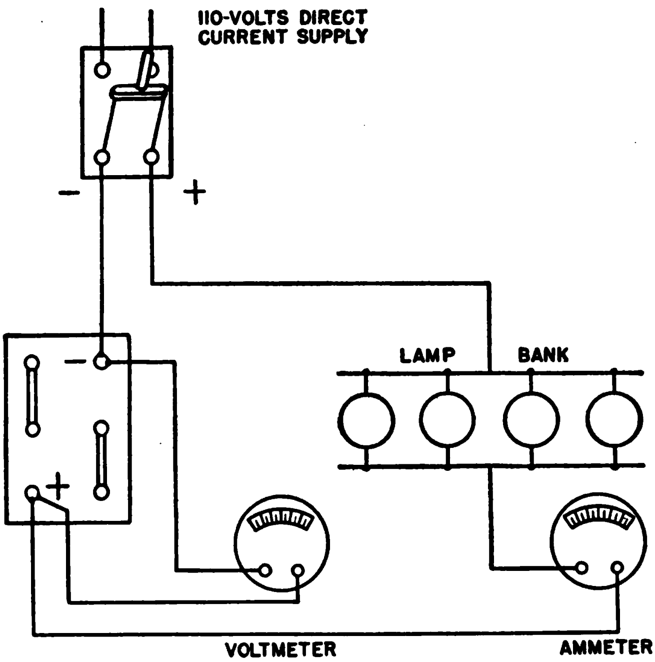



FIGURE 36.—Charging a single storage battery from a 110-volt direct current supply.

must be connected in parallel, since they should all receive the same voltage. Each lamp will allow approximately 1 ampere to flow through the battery, so if the charging rate in amperes is known, the number of lamps required will be equal to this rate. If 110-volt, 60-watt incandescent lamps are used, almost twice as many lamps must be connected in parallel since lamps of low wattage allow less current to pass. The wattage of the lamps used determines the number that should be connected in parallel. A total of approximately 100 watts should be used for each ampere of charging rate needed from a 110-volt d. c. supply. Under no circumstances should the battery be connected directly across the supply.

*b. Constant current charging (in series).*—Several batteries may be charged in series on a 110-volt d. c. supply more efficiently than charging each battery alone. With a single battery, the extra energy used by the lamps is wasted. However, there is a limit to the number of batteries that may be charged in series since the combined voltage of

all the batteries in series at the end of the charging period should always be lower than the voltage of the d. c. supply. Thus, assuming that the voltage of each battery when charged rises to 7.5 volts, up to 14 batteries ($14 \times 7.5 = 105$) can be charged in series. A variable resistance or rheostat should be connected in series with the batteries so that the charging current can be regulated as shown in figure 37.

*c. Constant potential charging (in parallel).*—(1) The constant potential system of charging has many advantages over the series system. It costs as much to charge one battery on the series system as

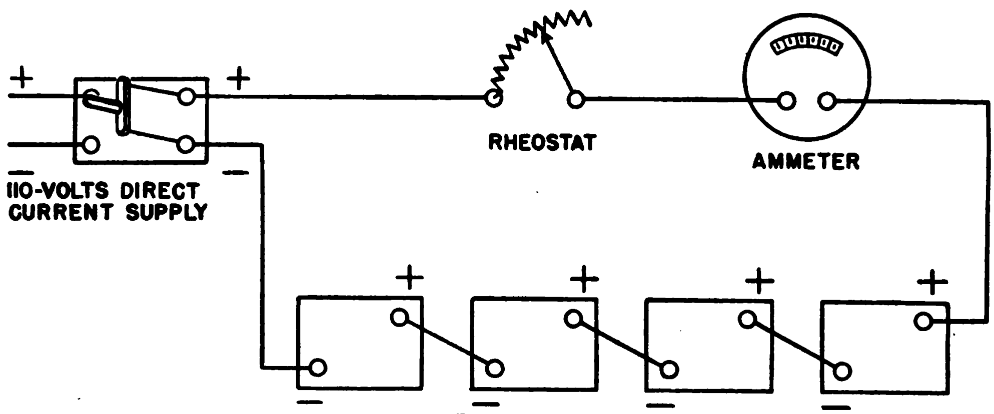



FIGURE 37.—Charging batteries in series from a 110-volt d. c. supply.

it does several, since the charging current is the same and the electrical energy converted into heat in the lamps or rheostat is wasted. In the constant potential system, the current is taken by the battery only as it is needed and no energy is wasted. The battery can be left on charge without constant watching, for as the battery becomes charged its voltage increases, less current is taken by it, and the chance of damage from overcharge is small. About 8 hours is usually sufficient for charging a battery by the constant potential system, as against 24 hours in series charging.

(2) Generators of 7.5 voltage rating are used for constant potential charging. These generators are usually driven by motors run from power supply lines. The batteries to be charged are all connected across the generator terminals (the positive terminals of the batteries are connected to the positive terminal of the generator). The charging rate is determined by the voltage of the battery. With a battery that is discharged (having a voltage below 6 volts), there will be a decided difference in voltage between the battery and the generator. This difference will cause a fairly high charging current to flow through the battery when it is first connected to the generator,

giving the desired higher starting rate. As the battery becomes charged, its voltage will increase and since the generator voltage remains nearly constant, the difference in voltage will diminish, thereby giving the desired lower finish rate. The battery draws no appreciable current as it reaches the fully charged condition of 7.5 volts and is said to "float" on the line. No damage will be done, therefore, to a battery that is left on the line after it has been fully charged by constant potential charging. Should a battery need to be charged at a lower rate, a special resistance can be put in series with the individual battery to regulate its charging current. A rheostat is usually provided to regulate the generator voltage.

(3) The number of batteries that can be charged on one generator is limited by the rated current output of the generator. The total of the charging currents required for all the batteries should not exceed the rated current output of the generator. Figure 38 shows the use of a motor-generator set for constant potential charging.

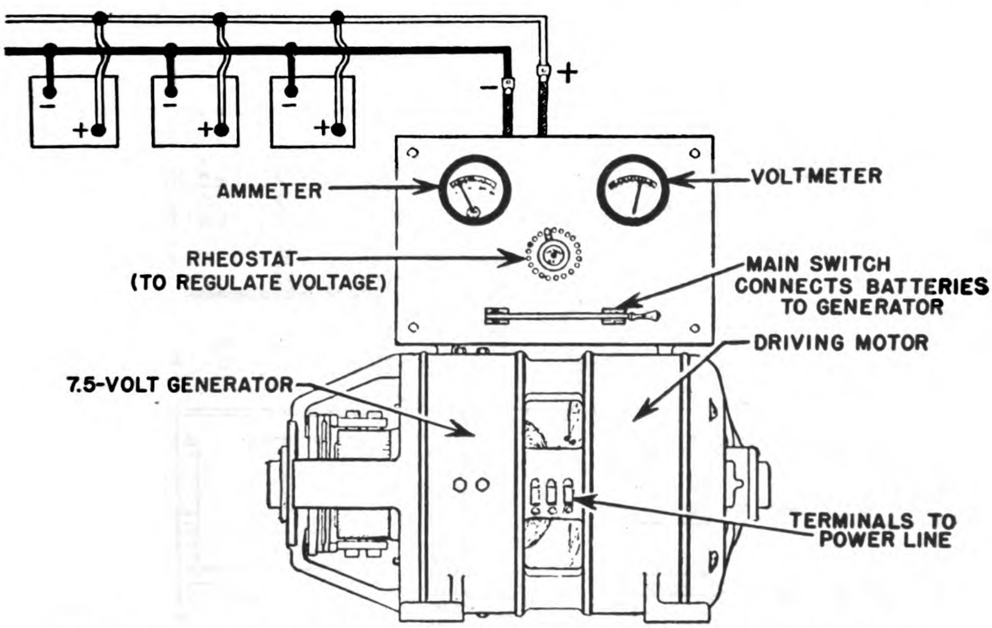



FIGURE 38.—Constant potential charging from a 7.5-volt motor-generator set.

(4) A constant potential apparatus sometimes consists of a 15-volt generator or two 7.5-volt generators on one armature shaft driven by a motor. Three heavy wires with the middle one acting as a neutral wire are then provided to supply direct current for charging the batteries. Six-volt batteries can be charged by connecting either the positive or the negative terminal to the corresponding outside wire and the other terminal to the neutral wire. Twelve-volt bat-

teries can be charged by connecting their two terminals to the correct outside wires. When putting batteries on to charge, it is best to get the same number of cells on both sides of the neutral wire so that the load is equally distributed between the generators. Figure 39 shows how the batteries are connected for constant potential charging with a three-wire system.

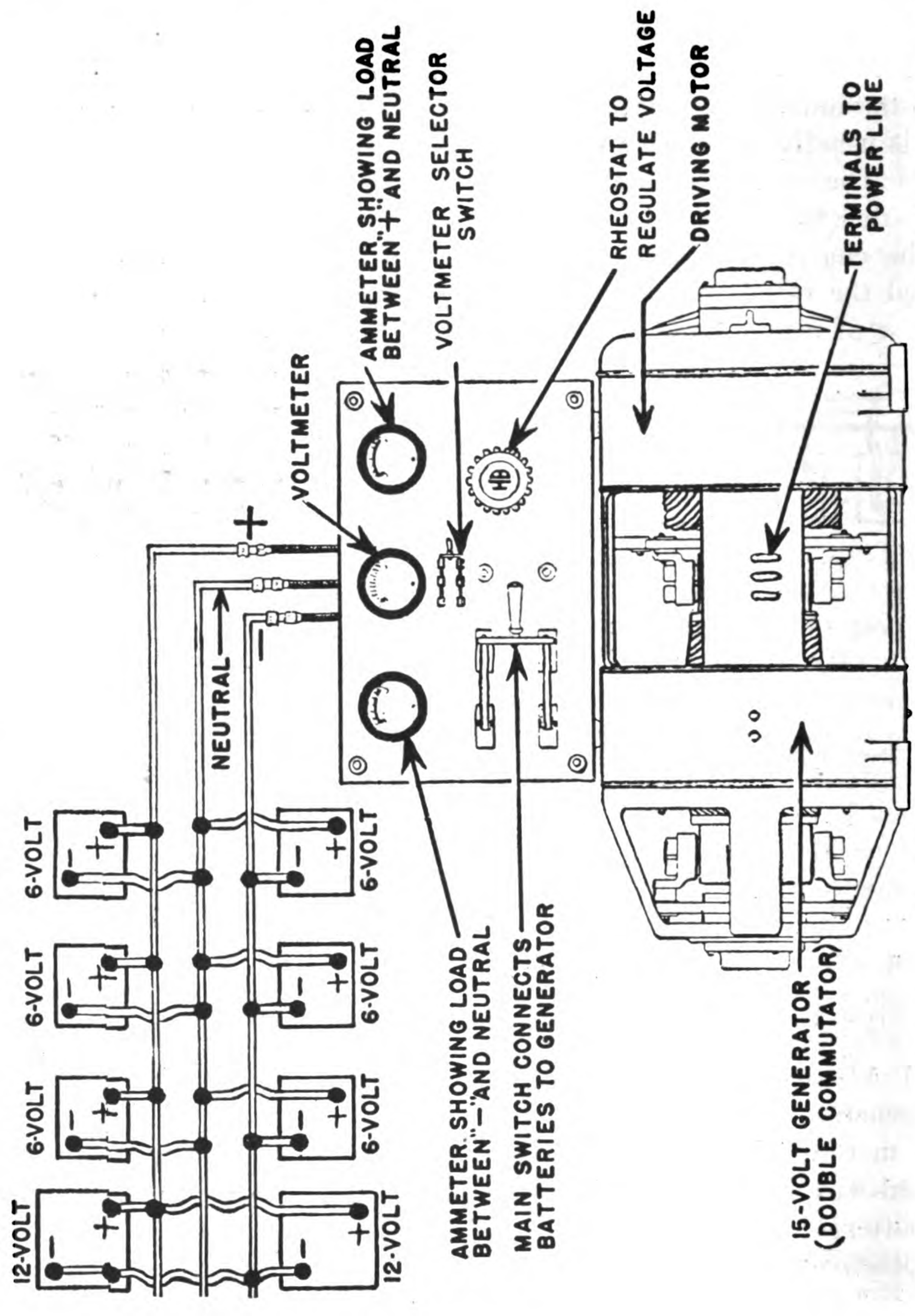



FIGURE 39.—Three-wire constant potential charging system showing how both 6- and 12-volt batteries may be charged at the same time.

(5) The current flowing in each of the outside wires to and from the generator terminals should not exceed the current rating of the charger unit. The current required, therefore, to charge all of the 6-volt batteries between either one of the outside wires and the neutral wire plus all of the 12-volt batteries between the two outside wires should not exceed the current rating of the generator.

*d. Rectifiers.*—When alternating current is the only source available and a rotary converter or an a. c. motor-d. c. generator set is not convenient or is too costly, various rectifiers can be used to convert alternating current to direct current. A rectifier is a device which will allow current to flow through it in one direction only. Thus, when alternating current is sent through the rectifier, the current supplied from it flows in one direction only.

(1) *Bulb rectifiers.*—(*a*) Gas-filled bulb rectifiers, such as the Tungar and the Rectigon, are in general use. They supply constant current charging and give satisfactory operation where the number of batteries on charge is small. The specially constructed bulb acts as an automatic valve, allowing current to go through it in one direction only. The important units of the bulb are a graphite disk and a tungsten filament (fig. 40) placed about ½ inch apart. When the disk and the filament become warm, current flows from the graphite disk to the tungsten filament, but not in the reverse direction because of the repulsing property of the inert gas (usually argon) within the tube.

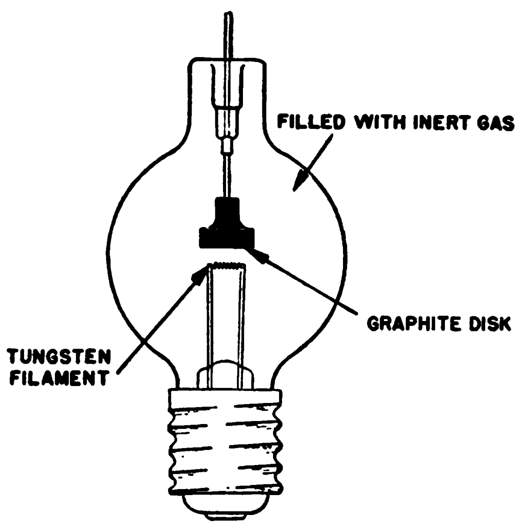



FIGURE 40.—Rectifier bulb.

(*b*) The remainder of the rectifier consists of either a variable transformer or a rheostat, either or both of which may be used to control the rate of charge. The transformer has a low-voltage wind-

ing that provides current for the tungsten filament of the rectifier bulb. The bulb rectifier is made in a variety of sizes varying in capacity from 1 to 30 batteries. The batteries must be connected in series with this type of charger. When more than 15 batteries are charged with a 110-volt a. c. supply, it is necessary to use a full wave charged with two bulbs. The internal circuits of a two-bulb rectifier are arranged so that one-half the alternating current flows through one bulb and the other half (flowing in the opposite direction) flows through the other bulb. This causes a continuous flow of direct current from the charger to the batteries being charged. Since both halves of the alternating current are used, this type charger is much

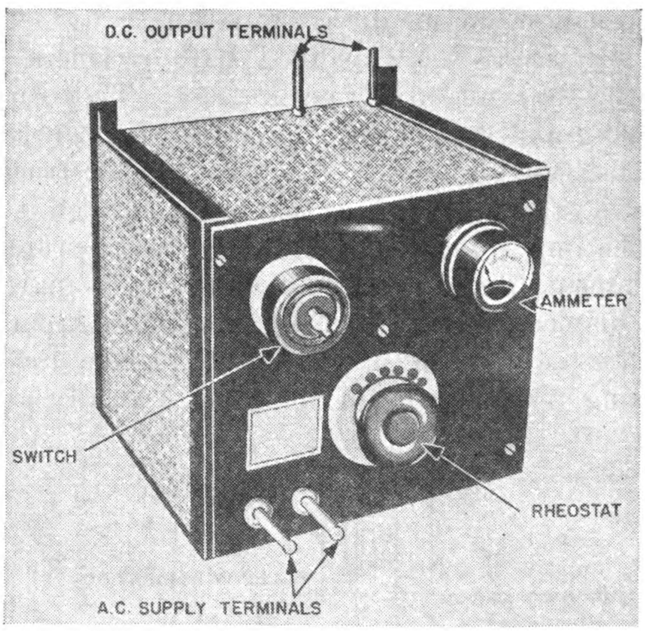



FIGURE 41.—Bulb rectifier unit.

more efficient than the single bulb type. The rate of charge obtainable from the bulb charger depends directly upon the size of the bulb.

(*c*) When connecting the batteries to the bulb charger, set the adjustable transformer or the rheostat to the zero setting and then turn the switch on. After a few moments, the bulb will become warm and then the adjustable transformer or rheostat can be regulated to obtain the desired charging current. A direct current ammeter is mounted on the charger to indicate the charging current. A bulb rectifier unit is shown in figure 41.

(2) *Copper-oxide rectifier.*—This rectifier consists of a group of copper disks oxidized on one side, strung through their centers on

an insulated rod, and clamped together. Current flows from the copper-oxide sides of the disks to the adjacent copper sides but will not flow from the copper sides to the copper-oxide sides. The rectifying principle depends upon this peculiar property of these copper-oxide disks. This rectifier is not very efficient for charging; however, its simplicity, ruggedness, and long life are desirable features.

(3) *Trickle chargers.*—In many cases it is possible to have a rectifier give batteries a small charging current over relatively long periods of time. A smaller rectifier can be used than would be necessary if the cells were charged at a high rate. Because of the low charging rate, these small battery chargers are referred to as trickle chargers. Trickle chargers may be built using almost any type of circuit and rectifier unit so long as satisfactory efficiency is obtained. Copper-oxide rectifiers, in connection with a transformer, give satisfactory trickle charging.

*e. Rapid charging.*—Many experiments are being made to develop rapid battery charging. What is ordinarily considered a dangerously high charging rate may be perfectly safe when properly controlled. The main difficulty encountered is that conditions in the battery vary and unless the materials in the battery are in good condition, rapid charging may seriously affect the battery. Further studies of battery properties and charging requirements may lead to a radical change in charging time.

**30. Maintenance and testing.**—The performance of a storage battery is considerably affected by the conditions under which it operates. In order to obtain good service from a battery, it is necessary to know the correct methods of maintenance.

*a. Corroded terminals.*—Terminals and connectors are frequently covered with a greenish deposit. This is a corrosion due to spilled electrolyte or to seepage of electrolyte through the terminal post seals. It should be scraped or brushed off with a stiff brush. Washing with ammonia or a solution of baking soda and water will neutralize any electrolyte remaining on the metal surfaces. After the terminals are rinsed and dried, a thin coating of vaseline will retard further corrosion.

*b. Filling with distilled water.*—(1) The battery should be kept filled at all times by adding distilled water to the level recommended by the manufacturer (usually about 3/8 inch above the tops of the separators). It should never be filled above this point because the electrolyte must have room to expand without running over. A self-leveling syringe, which has a small hole in the nozzle about 3/8 inch above the tip, can be used for filling batteries. With the tip of the

syringe resting on the tops of the separators, water added above the hole in the nozzle is sucked out. Only pure water should be used, as mineral impurities present in most water will interfere with the chemical action in the cell.

(2) Ordinarily, water is the only loss from the electrolyte. Some water is lost by evaporation, but most of the loss is due to the action of the charging current which decomposes the water and forms gases which are given off through the ventholes. Acid, which is not lost from the battery by evaporation or decomposition, should never be added to the cells. If electrolyte is spilled from loose vent plugs or by adding too much water, it should be replenished only by adding a solution of correct specific gravity. Strong acid solution (never above 1.400 specific gravity) should not be added since it is injurious to both plates and separators and will make hydrometer readings meaningless. Batteries with high specific gravity should be adjusted immediately by removing some electrolyte and adding water, then charging and making further adjustment in the same way until proper specific gravity is obtained.

(3) Water and sulphuric acid do not mix readily unless stirred or agitated. Therefore, specific gravity readings should not be taken until the battery has been in use for a short time after the addition of water. When the temperature is below freezing, water should be added only when the engine is to be run, so that the charging current will mix the water with the electrolyte. If water is added in cold weather and the battery is not charged immediately, the water will probably freeze.

*c. Specific gravity readings.*—Specific gravity is the weight of a substance compared to the weight of the same volume of chemically pure water at 4°C. (39.2°F.). The specific gravity of sulphuric acid is 1.835; that is, sulphuric acid is 1.835 times heavier than water. The electrolyte of a storage battery is a mixture of water and sulphuric acid in such proportions that when the battery is fully charged it has a specific gravity of 1.280 at 80°F. Since the amount of sulphuric acid in the electrolyte changes with the amount of charge, the specific gravity of the electrolyte changes with the amount of charge. This provides a convenient way of measuring the degree of charge in a battery.

(1) *Hydrometer.*—(*a*) Specific gravity of the electrolyte can be measured by a hydrometer syringe (fig. 42). A reading is taken by drawing sufficient electrolyte into the syringe to float the hydrometer element within the glass tube. For convenience, the reading is spoken of as being 1150, 1200, 1280 etc., instead of 1.15, 1.2, 1.28 etc., which

is correct. The electrolyte is returned to the cell by compressing the bulb, and the reading of the next cell can then be taken.

(*b*) Specific gravity readings of from 1270 to 1285 indicate that the battery is fully charged. Readings between 1200 and 1215 indicate that the battery is more than half discharged, and starter and accessories should be used sparingly until the battery is again fully charged.

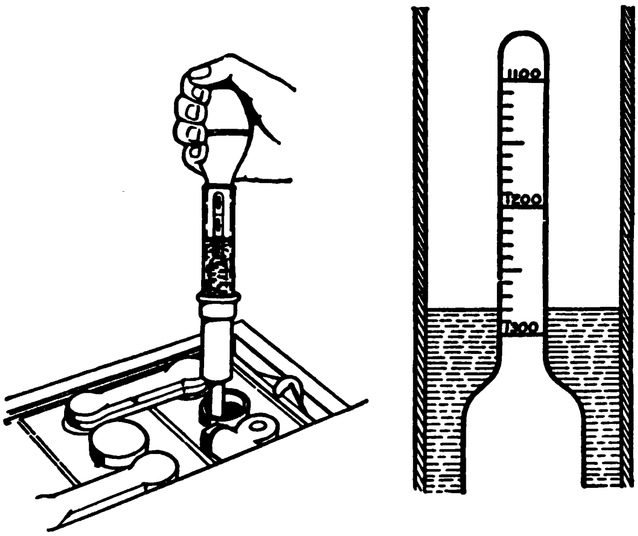



FIGURE 42.—Taking specific gravity reading of a battery with hydrometer syringe. (A close up view of a 1280 reading is shown at the right.)

Readings between 1125 and 1140 indicate that the battery is nearing a discharged condition and immediate charging is necessary, otherwise serious damage will result.

(2) *Temperature correction.*—All hydrometer readings given are usually based on the normal temperature of 80° F. for the electrolyte. This refers to the temperature of the liquid itself and not to the temperature of the surrounding atmosphere. To make temperature correction, add 1 to the hydrometer reading for every 2.5° above 80° F. and subtract 1 for every 2.5° below 80° F. For example, if the reading is 1250 at 100° F., add 8 to give a corrected reading of 1258. If the reading is 1270 at 20° F., subtract 24 to give a corrected reading of 1246. Figure 43 shows a chart to follow for temperature correction. Some storage battery manufacturers use other than 80° F. as a base for temperature correction. It is usually unnecessary to make allowance for temperature variations, but it is well to bear them in mind, otherwise the hydrometer reading will be misleading.

(3) *Variation in cell readings.*—If the specific gravity of any cell is more than 50 points below the other cells in the battery, it is an indication that some trouble has developed in this cell. An average

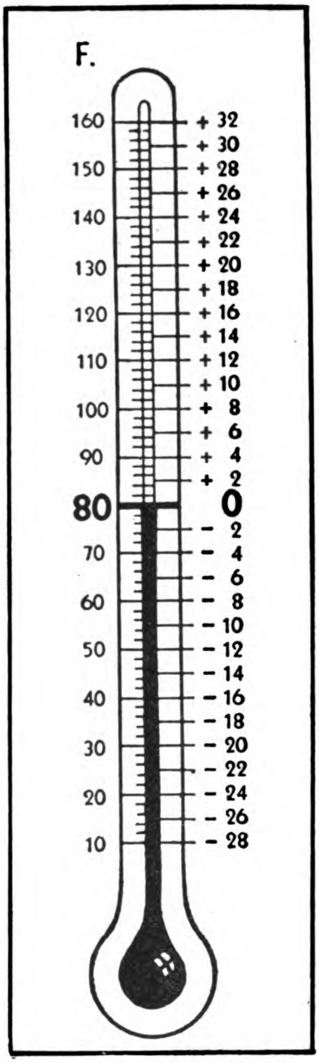



FIGURE 43.—Temperature correction chart of battery specific gravity.

of several readings should be made rather than just one reading to make sure of the variation. Variation in cell readings may be due to more sulphate remaining on the plates in one cell than others, short circuits inside the cell, putting too much water in the cell causing the electrolyte to overflow, or loss of electrolyte due to a cracked or leaky jar or container. Many battery troubles can be traced to the electrolyte becoming too low in the cells or to the battery not being snugly held by its clamps.

(4) *Equalizing charge.*—An equalizing charge, which is a continuation of a regular charge at about half the normal finish rate until all cells in the battery gas freely and uniformly, should be tried on batteries with variations in cell readings until specific gravity readings

show no increase. When the battery is in a vehicle, ordinary operation for a few days will sometimes bring the cells back to normal. If the battery does not regain its proper strength after an equalizing charge, it is an indication that the battery has some internal trouble and should be repaired or replaced.

*d. Voltmeter testing.*—(1) The individual cell voltage on charge and discharge can be determined by a voltmeter. When the voltmeter gives a positive reading, the cell terminal connected to the positive voltmeter lead is the positive terminal. A fully charged cell should read from 2.4 to 2.6 volts while on charge, depending on the age of the battery and the amount of charging current flowing. A cell that is discharged gives a reading of about 1.8 volts or less. When a cell is floating (neither charging nor discharging) while in operation, the voltage should be between 2.15 and 2.25.

(2) The quickest and surest method of determining the internal condition of the battery cells is to test them at a comparatively high discharge rate. Batteries having specific gravity readings below 1.200 must be fully charged before being placed on test. The cell voltages should be accurately tested under conditions which approximate battery operation in a vehicle. The load placed on a battery when discharging it at one and one-half times the 20-minute discharge rate is comparable to the load placed upon it when starting the engine. The 20-minute discharge rate is a capacity rating specified by the manufacturer. This rate, usually between 120 and 180 amperes, will completely discharge the battery in 20 minutes.

(3) The battery should be left on the test load for not more than 1 minute. A comparison of the cell readings while they are discharging at this test rate will indicate their condition. A cell in a discharged condition gives a lower voltage reading because the larger amount of lead sulphate on the plates and the lower electrolyte strength offer added resistance to the flow of current. Batteries having variations of .15 volt or more between cell readings are not serviceable.

(4) There are several different types of equipment used to obtain the voltage readings of a battery while it is under load. The cheapest and handiest equipment is the individual cell tester consisting of a voltmeter and a heavy resistor. A discharge rate of from 180 to 200 amperes is obtained from the cell when the prongs of the tester are placed upon the cell terminals. One disadvantage of this tester is that the discharge rate is not adjustable for different sized batteries; a 19-plate battery would be discharged at the same rate as an 11-plate battery. This method of testing is slow because each cell must be tested separately. However, it is convenient for testing the battery while in a vehicle.

(5) Special electrical test sets, consisting of three voltmeters (or one voltmeter operated by switches for the separate cells), an ammeter, and a variable carbon pile rheostat, are sometimes used for testing batteries. Four leads are usually provided to be applied to the cell terminals so that voltage readings can be taken of each cell while on discharge. The two outer leads, which are connected to the battery post terminals, are made of heavy cable so that they can also carry the discharge current through the rheostat. The variable rheostat is used to discharge the battery at the desired rate which is recorded on the ammeter. This type of equipment provides a quick means for testing all the battery cells together.

**31. Battery conditions.**—*a. Freezing.*—(1) The freezing point of the electrolyte depends upon its specific gravity and the condition of the battery charge. When the battery is fully charged, the freezing point of the electrolyte is about 85° below 0° F. When the battery is completely discharged, the electrolyte contains a maximum amount of water and its freezing point approaches that of water, or 32° F. It is therefore evident that the battery should be kept close to a fully charged condition in cold weather to prevent the plates or container from being damaged by freezing.

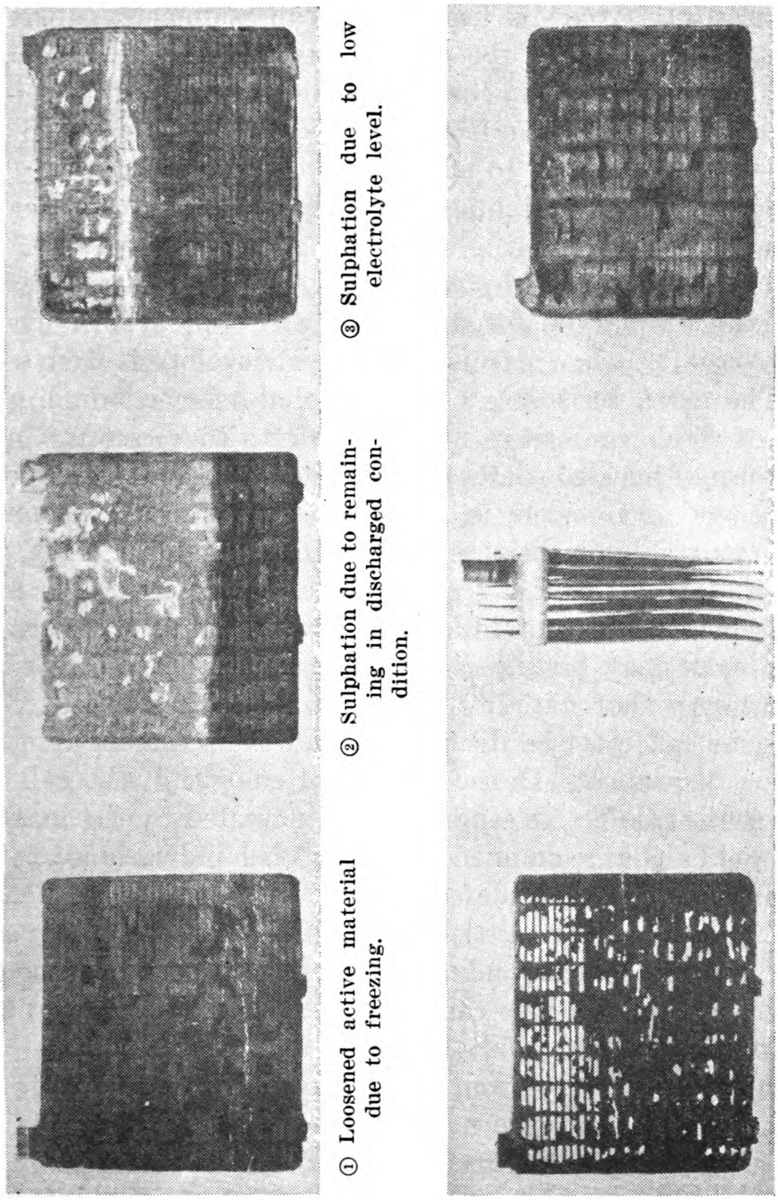
(2) Ice forces the active material from the plates and even cracks the plates and containers. As soon as a charge is given to a frozen battery, the grids expand and the loosened material drops to the bottom leaving exposed grids (fig. 44 ①). A battery should never be left out in cold weather after it has become discharged in trying to start a vehicle.

*b. Sulphation.*—(1) The lead sulphate, which forms on the plates during discharge, grows into a hard, white, crystalline formation when the plates are permitted to remain in a discharged condition. This formation, known as sulphation, closes the pores and destroys the active area of the plates. If water is not added at regular intervals, the electrolyte level will soon fall below the plate tops causing sulphation of that portion of the plates exposed to air (fig. 44 ② and ③).

(2) Lead sulphate is a nonconductor of electricity, therefore it reduces the active area of the plates and materially reduces the ampere-hour capacity of a battery. If not too pronounced, sulphation can be removed only by prolonged charging at a very slow rate, usually the finish rate. The battery may require charging for several days to restore it to a fully charged condition.

*c. Deterioration.*—Storage batteries will wear out from use, especially in the positive plates, since the active material softens and

tends to fall to the bottom of the container as sediment. The action of the gas escaping from the pores of the plates and the agitation of the gas bubbles rising to the surface of the electrolyte hasten the shedding of active material and shorten the life of the battery.



① Loosened active material due to freezing.

② Sulphation due to remaining in discharged condition.

③ Sulphation due to low electrolyte level.

④ Active material shed in worn-out plate.

⑤ Buckled group of plates due to overcharging.

⑥ Disintegrated plate due to repeated overdischarge.

FIGURE 44.—Battery plate conditions.

Excessive gassing, therefore, should be avoided if long life is desired. A small amount of gassing, at low rates and for a short time at the completion of the charge, is not objectionable; but violent gassing, having the appearance of boiling, should be avoided. A worn-out plate is shown in figure 44 ④.

*d. Overheating.*—When the battery is being charged or discharged, heat is produced by the chemical reactions that occur and by the resistance of the battery to the passage of current. This heat does not become injurious until the temperature rises above 110° F. and it may be somewhat higher for a brief period of time without injuring the plates or separators. Excessive heat, which causes quick expansion of the plates, is likely to warp the plates and disintegrate the active material. High temperature in the cell shortens the life of the separators and hence prevents them from properly separating the plates. Acid in the electrolyte tends to attack and destroy separators (particularly wood separators) at temperatures above 110° F. Overheating is usually caused by overcharging or charging at too high a rate.

*e. Buckled and disintegrated plates.*—Battery plates that have been allowed to stand discharged for some time will tend to buckle when recharged, especially when excessive heat is developed from overcharging. The extra resistance of the sulphate formed during the long period of discharge causes unequal stresses to be set up in the plates. A group of buckled plates is shown in figure 44 ⑤. Repeated overdischarge and overcharge is likely to cause unusual expansion which sometimes results in disintegration of the plates (fig. 44 ⑥).

*f. Sediment.*—Owing to the gradual shedding of the active material from the plates, sediment collects in the bottom of the cells. In time this sediment may fill the sediment space in the bottom of the container causing a short circuit at the bottom of the plates. When this happens the cell must be dismantled and the sediment removed.

*g. Defective insulation.*—Defective insulation within the cell, due to high sediment or defective separators, is indicated by the inability of the cell to hold a charge on open circuit. Other indications of short circuit within the cell due to defective insulation are undue heating of the cells upon charging; little or no voltage or specific gravity rise after a prolonged charge; and the impossibility of making the cells gas properly. Such conditions can be remedied only by dismantling and rebuilding the battery.

*h. Best battery practice.*—From a cost standpoint, a new battery is usually less expensive than the necessary repairs to a defective one. To keep a battery in satisfactory condition and to insure long life, keep the battery clean outside; add pure water at regular intervals; and maintain a healthy state of charge without excessive overcharging.

## Section IV

## BATTERY IGNITION SYSTEM



**32. Automobile ignition.**—All internal combustion engines must have the fuel charge within the cylinders ignited by some means. To accomplish this, two methods of ignition are used; ignition by compression and ignition by an electric spark.

*a. Compression ignition.*—The compression method of ignition, although one of the oldest, has only recently been commercially applied. When a gas is compressed, it becomes hot. This principle is used in the Diesel engine. Air is compressed in the cylinder until it is sufficiently hot to ignite the injected fuel charge.

*b. Spark ignition.*—The electrical method of ignition is almost universally used in automotive engines because it is effective with different grades of fuels, readily and accurately controlled, and the electric spark ignites the fuel charge almost instantaneously.

**33. Spark ignition systems.**—*a. Fundamental units.*—A spark ignition system is composed of the following fundamental units:

(1) A source of electrical energy.

(2) A transforming device (coil) to increase the electrical pressure of the energy.

(3) An interrupting device (breaker contact points) to determine the proper timing of the spark.

(4) A distributor to direct the spark to the different cylinders in the proper order.

(5) A spark gap (spark plug) for each cylinder of the engine.

(6) Proper wiring and switches to bring these units together to form the ignition system. The wiring of a motor vehicle is customarily of the single-wire type; that is, only one wire leads to each electrical unit, the other side of the unit being grounded or connected to the frame so that the current returns through the metal of the frame by the most convenient route. Complete two-wire circuits have been used, but the single-wire system is satisfactory and much cheaper.

*b. Current source.*—Two systems are used for motor vehicle ignition; battery and magneto. The battery system obtains its current from a storage battery and a generator, while the magneto system (sec. V) obtains its current by the relative movement between a coil and the poles of a permanent magnet. The magneto ignition system is generally more constant and dependable, needs less care, and does not have a battery to run down and wear out; but these advantages are discounted by the fact that most vehicles need electric lights and an electric starter. The battery system, which permits both, is the most extensively used, although the magneto system is frequently used on racing cars and agricultural tractors where only ignition is required.

*c. Types of ignition.*—(1) A much higher voltage than the battery or magneto supplies is necessary to produce the spark for ignition. An increase in the compression of the fuel mixture further increases the voltage needed. For this reason, the higher compression engines used today require a much higher voltage to ignite the fuel than was required by early low-compression engines.

(2) Low tension and high tension ignition are the two methods used to increase the voltage of the battery or magneto sufficiently to make an ignition spark in the engine cylinders. In the low compression engines used on early motor vehicles, a comparatively small increase of the original voltage was required to make an ignition spark. Low tension ignition, with the spark plugs and the current source included in one circuit, produced the desired results. High tension ignition, in which the current source is in one circuit and the spark plugs in a second circuit of a much higher voltage, is used to obtain the much larger increase in voltage necessary for an ignition spark in high compression internal combustion engines.

**34. Low tension ignition.**—Low tension ignition is called the make-and-break type because an electrical circuit of low voltage is made and broken to produce the electric spark for ignition. Contact points that make and break the circuit are located in the combustion chamber of the engine cylinder (fig. 45). A low tension coil is used to increase the voltage as the spark contacts separate. The interruption and proper distribution of the current is accomplished by the mechanism which opens the contacts for the spark gap in the individual cylinders. Make-and-break ignition is no longer used for automotive ignition but is still extensively used on low speed stationary engines and small marine power plants. The principle employed in make-and-break ignition may be illustrated by the arc obtained when the two leads from a set of dry cells or a storage battery are struck together and quickly snapped apart. A bluish-white spark will be

produced at the point of separation because of the interruption to the current. A spark produced in this manner is inefficient for the purposes of ignition.

*a. Low tension coil.*—To increase the efficiency of a spark for ignition purposes, a coil of several hundred turns of insulated copper wire wound on a core of soft iron is connected in series with the battery and the spark gap. The core is generally made of a bundle of soft iron wire so that it will magnetize and demagnetize quickly. Such a coil is usually termed a kick coil, because if a current going through the coil is suddenly interrupted by breaking the circuit, a flashy spark of considerable intensity or kick will occur at the point of breaking. The fuel charge is ignited by a spark produced in this manner between the spark contacts inside the engine cylinder.

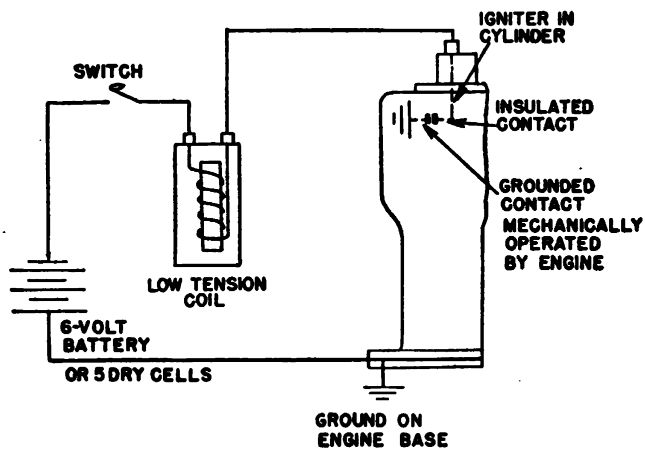



FIGURE 45.—Make-and-break ignition circuit.

*b. Self-induction.*—(1) The increased spark is brought about by the inductive effect of the coil during demagnetization. The low tension coil is an electromagnet which has magnetic lines of force set up around it when a current is flowing through it. At the moment the circuit is broken, the magnetizing current stops and the magnetic lines of force collapse. Thus, the electromagnet is demagnetized and the magnetic lines of force move rapidly toward the core and cut each turn of wire on the coil (fig. 46). This cutting of the wire by the collapsing magnetic lines of force induces a voltage in the coil which causes a current to flow in the same direction as the original magnetizing current from the batteries. This induced voltage is only momentary, but due to the multiplying effect of the turns, it may reach a maximum voltage across the entire coil of 200 to 250 volts, depending upon the number of turns and the design of the coil. This self-induced

voltage is produced at the moment the contact points are separated and is sufficient to break down the resistance of the air gap between them.

(2) Self-induction varies in different coils since it depends upon the length, cross sectional area, shape, and quality of the iron used and the size and number of turns of the wire in the coil. These are important facts which should be considered in replacing a defective coil.

c. *Hydraulic analogy.*—The action of a self-induction or kick coil may be compared to the water hammer produced in a pipe line. Stopping the flow of water by suddenly closing a valve will produce

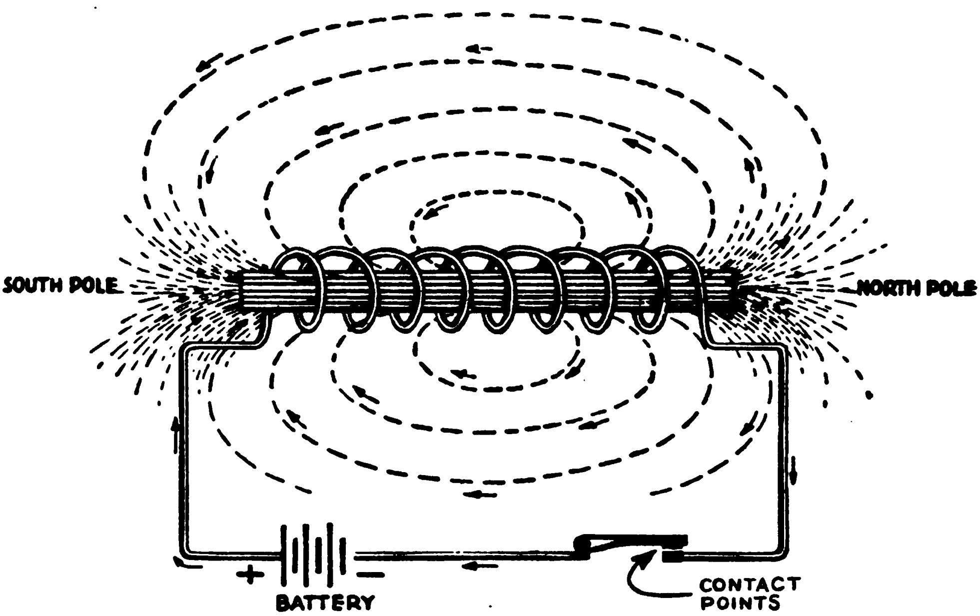



FIGURE 46.—Collapse of magnetic field around a low-tension coil (demagnetization) produces induced kick voltage.

a terrific blow on the valve known as water hammer. The instantaneous pressure causing the water hammer may be several times that of the ordinary pressure that caused the water to flow when the valve was open. It will also be noted that this instantaneous or kick pressure is in the same direction as the original pressure, tending to maintain the flow of water. The kick voltage in the low tension make-and-break coil acts in the same manner.

**35. High tension ignition.**—In high tension ignition, the low voltage of the current supply is transformed into high voltage so that the current will be able to jump a stationary spark gap inside the cylinder. Hence, high tension ignition is known as the "jump

spark" type. Two circuits, inductively coupled by a high tension coil, are used: the primary or low voltage circuit, which includes the current source, ignition switch, current interrupter, condenser, and primary winding of the coil; and the secondary or high voltage circuit, which includes the secondary winding of the coil, distributor, and spark plugs. (See fig. 47.)

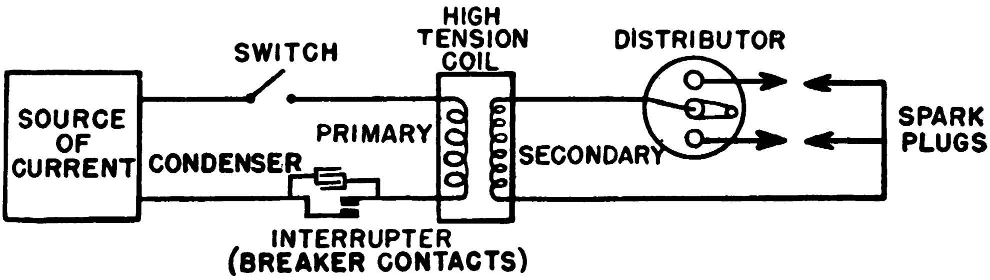



FIGURE 47.—Fundamental units of a jump spark ignition system.

*a. High tension coil.*—(1) A high tension coil has its two windings on a core of soft iron. This coil, which produces the high voltage required to jump the spark gaps, is known as an induction coil. The primary winding contains comparatively few turns while the secondary winding contains many turns. Either winding can be placed next to the core, but the present practice is to wind the secondary next to the core and the primary outside the secondary. A coil of this design is not highly efficient since the magnetizing current flowing through the primary winding will be farther away from the core; however, it is simpler in construction and much cheaper to manufacture than a more efficient type.

(2) The core is about $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter and 4 to 6 inches long. It is made longer than the winding so that practically all the lines of force that leave its edges encircle the winding. The core usually consists of a bundle of soft iron wire, or sometimes of thin soft iron strips or laminations, which prevent eddy currents induced within the core by magnetic action from flowing around the core. These eddy currents, which are lost energy, flow in a continuous circle around a solid iron core and heat it.

(3) The secondary or high tension winding is made up of several thousand turns of small copper wire insulated with enamel or silk. These turns are wound around the core in many layers, each layer running the entire length of the winding. The layers are insulated from each other by paraffin waxed paper. An induction coil with the secondary winding next to the core is shown in figure 48.

(4) The primary winding is insulated from and wound outside the secondary winding. It consists of a few layers of cotton covered or enameled copper wire, larger than that used for the secondary winding.

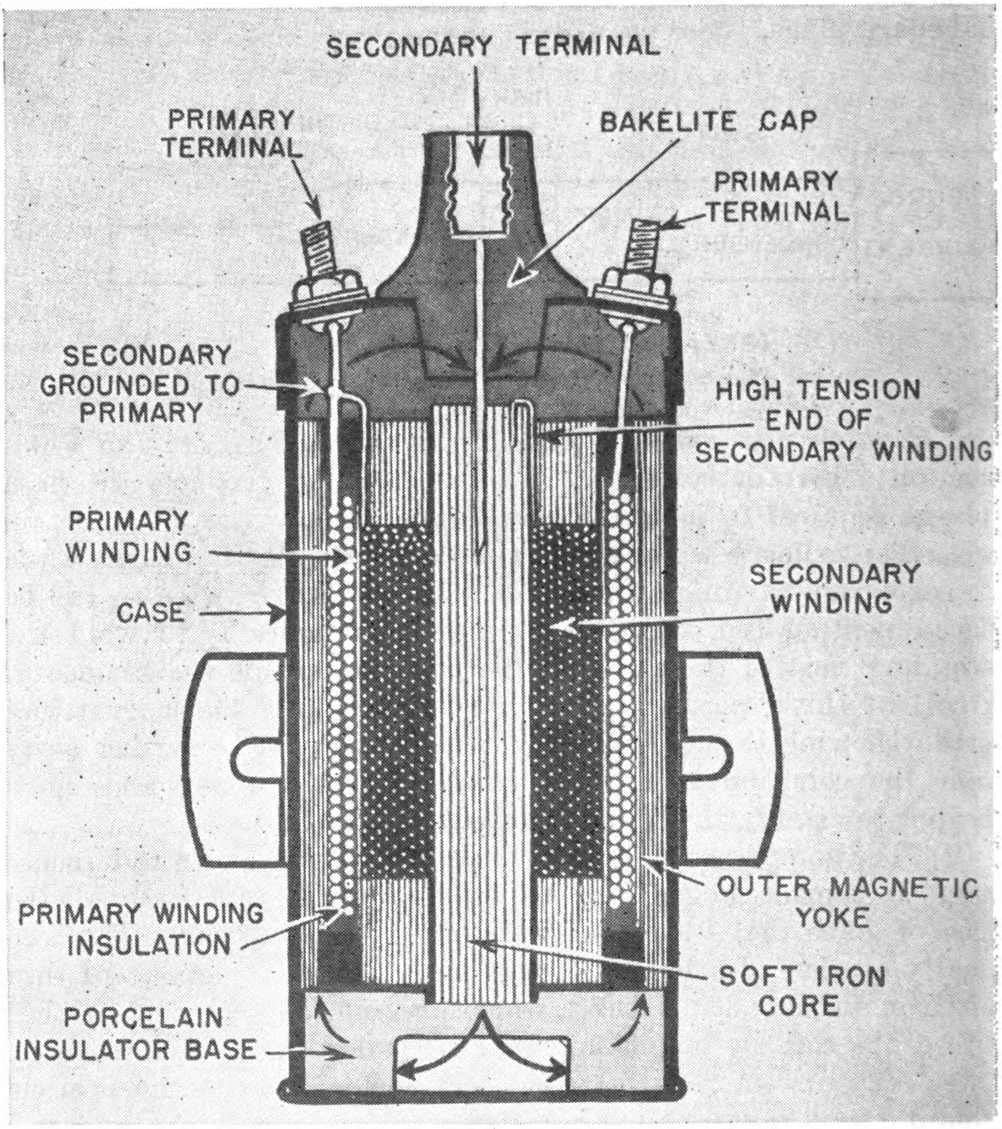



FIGURE 48.—Induction coil with secondary winding next to core. (Dark arrows in coil ends indicate magnetic circuit.)

(5) An outer cylindrical yoke of laminated iron usually encloses the windings and serves as a conductor for the magnetic field which is thereby strengthened. The core of the coil in figure 48 is insulated by the porcelain insulator in the base and by the bakelite cap which contains the secondary terminal. The high tension end of the sec-

ondary winding is connected to the secondary terminal and the cap and the other end is usually connected to the primary. The high tension end and secondary terminal can be connected by joining both to the thoroughly insulated core. When one end of the secondary winding is connected to the primary, this connection is made to the primary terminal that leads to the ignition switch. Manufacturers' instructions for properly connecting the coil should be closely followed.

(6) An induction coil with the primary winding wound next to the core must have a shell of bakelite or other insulating material to insulate the high voltages produced in the secondary winding. This type of coil can be made very efficient and will produce good sparks for all engine speeds if a well-designed magnetic circuit is used.

*b. Mutual induction.*—(1) The high tension coil relies on the inductive effect of the magnetism produced by the current in the primary winding to induce a high voltage in the secondary winding. This inductive effect of the two-winding coil is known as mutual induction. Mutual induction depends on the physical characteristics of the coil just as self-induction depends on the physical characteristics of a low tension coil.

(2) A voltage is induced in the secondary winding when the core is being magnetized or demagnetized by a current in the primary winding. The coil is demagnetized much quicker than it is magnetized, especially with the aid of a condenser across the breaker contacts (par. 36). As a result, the voltage induced in the secondary winding is much higher when the primary circuit is broken than when it is closed and the spark is set to occur at this time.

*c. Voltage.*—(1) The voltage produced in the secondary depends upon the ratio of turns in the primary and secondary windings. The larger the number of turns in the secondary in comparison to the number of turns in the primary, the larger the voltage that is produced in the secondary.

(2) The normal voltage necessary to jump the spark plug points under compressions of 90 to 110 pounds per square inch with the points properly adjusted (0.025 inch to 0.030 inch) is usually from 6,000 to 8,000 volts. The voltage must be increased in proportion to increases in compression. The insulation and construction must be able to withstand the momentary voltage produced in the secondary winding to jump the spark plug points.

*d. Insulation.*—Adjacent layers must be protected by insulation of a high quality so that there will be no chance for a spark to leap between the layers and cause a short circuit of some of the winding,

thereby reducing the available voltage. For insulating purposes, a material having a high dielectric or insulating strength should be used. The best dielectric materials are glass, mica, rubber, waxed paper, varnished cloth, and porcelain. It is a common practice to run thin waxed paper between the layers of wire and to impregnate the whole winding with wax. This prevents the coil from being affected by dampness and minimizes the possibility of break-down or puncture of the insulation. Varnished cloth is particularly suitable for insulating the primary and secondary windings, since it is flexible and thin enough to be wrapped around the windings.

*e. Primary resistance.*—Enough resistance should be included in the primary circuit to prevent overheating of the coil by a steady current when the switch is left on with the engine not running. This resistance should also tend to equalize the intensity of the spark at high and low engine speeds. If the primary winding of the coil has too low a resistance, an external ballast resistance is connected in series with the coil. The ballast resistance consists of a number of turns of high resistance wire that increases in resistance as it becomes hot from a steady flow of current. The resistance wire used is usually nichrome or german silver wire similar to that used in an electric toaster.

*f. Vibrating coil.*—An ignition system with a vibrator added to the induction coil is shown in figure 49. A vibrating coil is usually provided for each cylinder with the primary windings connected to terminals on the timer. The timer or revolving switch (driven by the camshaft of the engine) which connects the battery to the proper coil at the proper time is used for opening and closing the primary circuit. The vibrator contacts make and break rapidly each time the timer closes the circuit, causing a shower of sparks to be delivered at the plug. A safety gap (fig. 49) has been used on some ignition systems to protect the induction coil from excessive voltage in case there is a broken lead or other opening in the secondary circuit. Ignition systems using the vibrating coil are obsolete.

**36. Condenser.**—A condenser connected in parallel with the interrupter or breaker contact points is used in jump spark ignition systems to prevent sparking at the points. It also improves the action of the coil.

*a. Construction.*—A condenser is constructed of strips or sheets of tinfoil insulated by thin sheets of paraffined paper or mica. The alternate layers of tinfoil are connected in parallel, forming two groups, each group provided with a terminal for external connection (fig. 50). Rolled or cylindrical condensers are made by winding alternate layers of the tinfoil and the insulation into a tight roll. Direct

current cannot pass through a properly insulated condenser because there is no direct connection between the two groups of layers. If direct current passes through the condenser, it is short circuited or leaky and must be repaired or replaced.

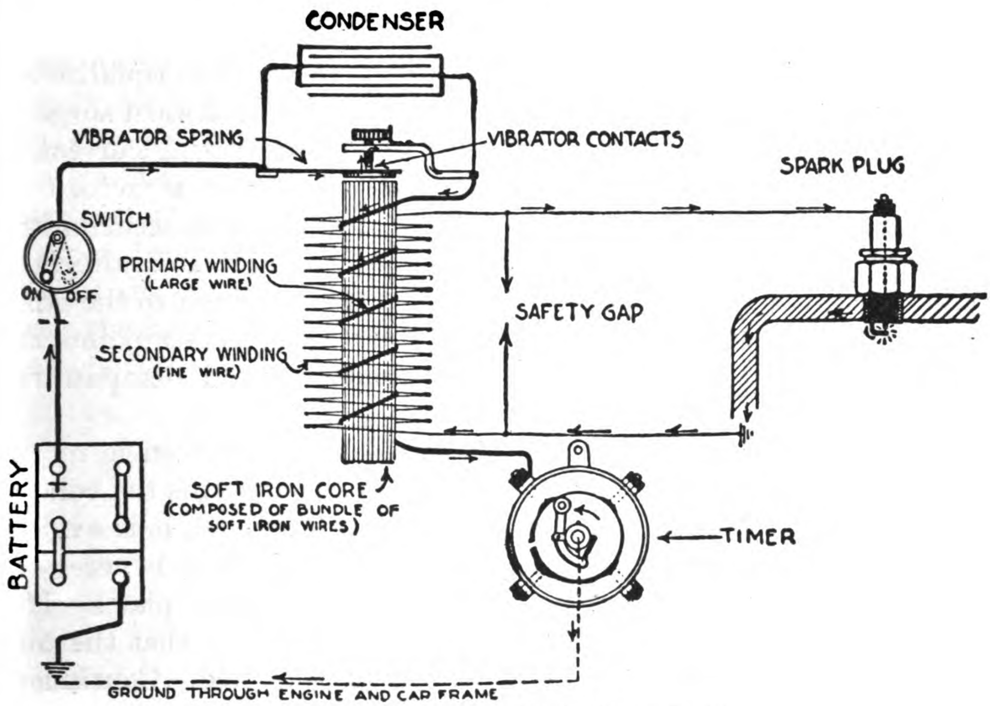



FIGURE 49.—Vibrating coil ignition circuit.

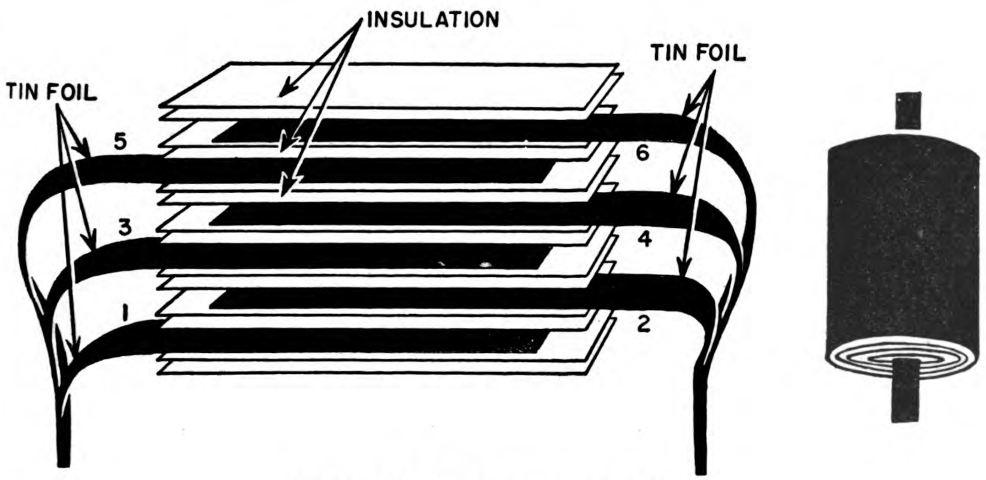



FIGURE 50.—Condenser construction.

*b. Operation.*—(1) When the primary circuit breaks, the induced kick voltage in the primary, caused by the collapsing magnetic lines of force, would ordinarily cause an arc across the contact points such as

occurs in low tension ignition. However, when a condenser is connected across the contact points, this kick voltage instead of overcoming the resistance across the contact points, charges the condenser. The side of the condenser which receives the surge is temporarily charged positively and the other side negatively. The condenser instantly discharges in a reversed direction through the primary winding and battery (or other source of current) in an attempt to equalize the potential on the two sides of the condenser. As the backward surge of current is opposite in direction to the original magnetizing current, it assists in quickly reducing the magnetism of the core to zero, thus speeding the collapse of the lines of force and aiding in securing the maximum induced voltage in the secondary winding. In reality, the current surges or oscillates from one side of the condenser to the other several times before it finally dies out, unless the contact points are closed beforehand to short circuit the condenser and dissipate the remaining charge.

(2) Since the condenser is subjected to a full kick voltage of the primary coil, that is, the 150 to 250 volts impressed across the contact points at the instant the primary current is interrupted, it is evident that a good dielectric material between the tinfoil plates is necessary to prevent a short circuit between the oppositely charged plates. If a flashy spark occurs at the contact points, it is evidence that the condenser has either become short circuited or disconnected. Continuous sparking at the contact points due to faulty condenser action will cause the points to become badly burned. The condenser might also be too small to handle the voltage induced by the coil with which it is used.

*c. Location.*—The condenser is usually mounted in the interrupter unit and sometimes in the coil housing, preferably as near to the breaker contacts as possible in order to be most effective. In either location it should be well protected against damage and moisture.

*d. Capacity.*—The capacity of a condenser depends on the size, number, and arrangement of the tinfoil plates, and upon the thickness and quality of the dielectric material between them. The actual number of square inches of tinfoil needed in a condenser depends upon the size of the wire and the number of turns in the coil windings, the shape and quality of the iron core, and the speed at which the circuit is interrupted. Its capacity is usually about one-half a microfarad (the microfarad is a unit of electrical capacity). The action of a good condenser of proper capacity usually results in intensifying the secondary voltage about 25 times. It should also eliminate arcs across the breaker contact points when they are separated to prevent them from pitting and burning.

*e. Hydraulic analogy.*—A better understanding of the action and function of the condenser can be had by hydraulic analogy. A flexible diaphragm connected across a water valve, just as a condenser is connected across breaker contacts, will simulate condenser action (fig. 51). If the valve is suddenly closed, cutting off the flow of water from tank *A* through the pipe to tank *B*, the momentum of the water will momentarily depress the diaphragm. However, it immediately rebounds, forcing a surge of water back through the pipe to tank *A*. In fact, the water surges back and forth several times before it comes to a standstill. The surge pressure caused by suddenly closing the valve is thus absorbed by the flexible diaphragm which prevents water hammer from damaging the valve. In like manner, the condenser absorbs the current surge in the primary circuit of the ignition coil when the breaker contacts are opened, preventing an arc across the contacts.

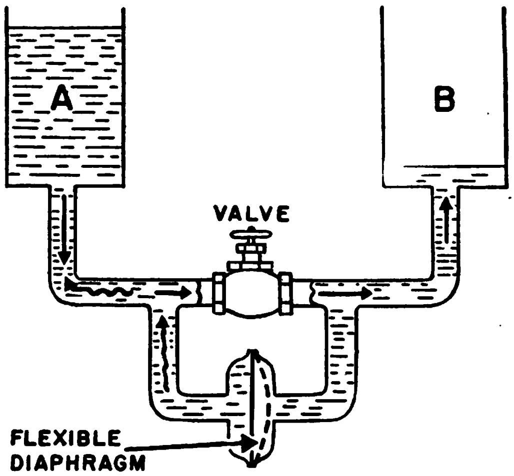


FIGURE 51.—Hydraulic analogy of condenser action.

**37. Timer distributor.**—The timer distributor unit used on the modern motor vehicle contains the breaker contacts which make and break the primary current and the distributor mechanism which supplies the secondary current to the plugs in their proper firing order. Figure 52 shows how the timer distributor is connected into the typical battery ignition system.

*a. Breaker contact points.*—(1) Breaker contact points must permit the spark plugs to fire accurately at high speed. Therefore the moving parts must be light, yet strong, and carefully built of high-grade materials. The breaker contact points are two small contact pieces, one stationary and one on a movable arm, normally held against the stationary contact by spring tension. The points are made of

tungsten or platinum alloy to resist burning and pitting and are hard enough to withstand the hammering action caused by the rapid closing of the breaker at high speeds. A small cam, with a lobe for each time the breaker is required to open per revolution, revolves and

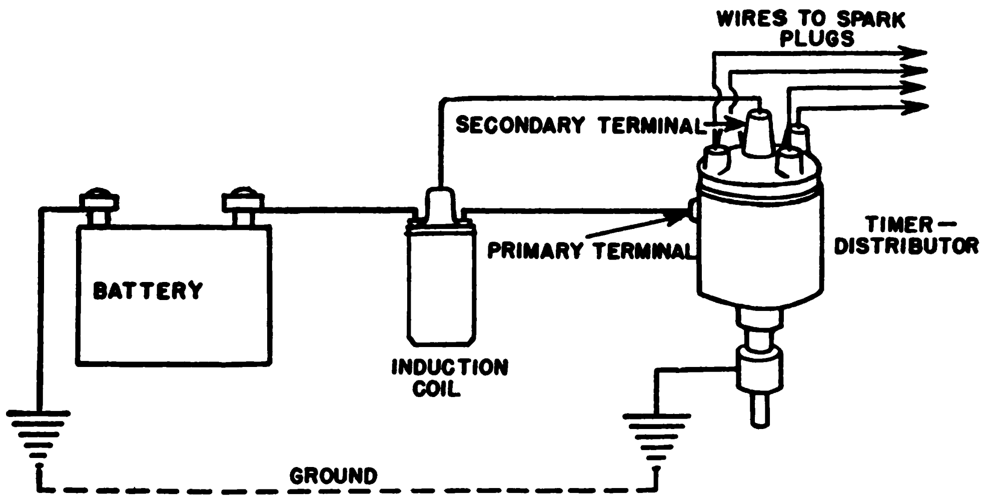
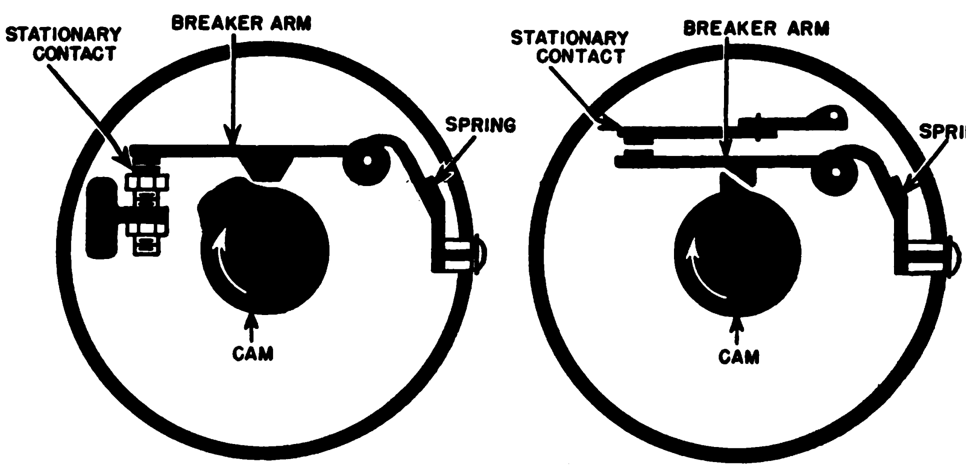



FIGURE 52.—Location of timer distributor in the typical battery ignition system.

pushes the movable breaker arm so that the contact points are separated. In this way, the current in the primary winding of the coil is interrupted every time a spark is required in one of the cylinders.




① Closed type. ② Open type.

FIGURE 53.—Circuit breakers.

(2) The usual circuit breaker used on modern vehicles is the closed circuit type (fig. 53 ①). The contact points normally remain in the closed position, being separated only when the breaker arm is lifted by a lobe of the breaker cam. The closed circuit type is more adapt-

able to high-speed engines because the points are in contact long enough to allow complete magnetization of the high-tension coil. This results in especially good sparks at slow starting speeds with less intense sparks at higher speeds when the time of contact is shortened.

(3) Early ignition systems used breakers of the open circuit type (fig. 53 ②) in which the contact points normally remain open and are closed only for a short period of time prior to the moment the ignition spark is desired. The open circuit breaker was originally developed for use with dry cells where current economy was highly desirable. It is not used on modern high-speed engines.

*b. The distributor.*—The function of the distributor is to direct the secondary current from the induction coil to the various spark plugs of a multicylinder engine in the proper firing order. The essential parts of the distributor are the rotor and the head or cap. (See fig. 54.)

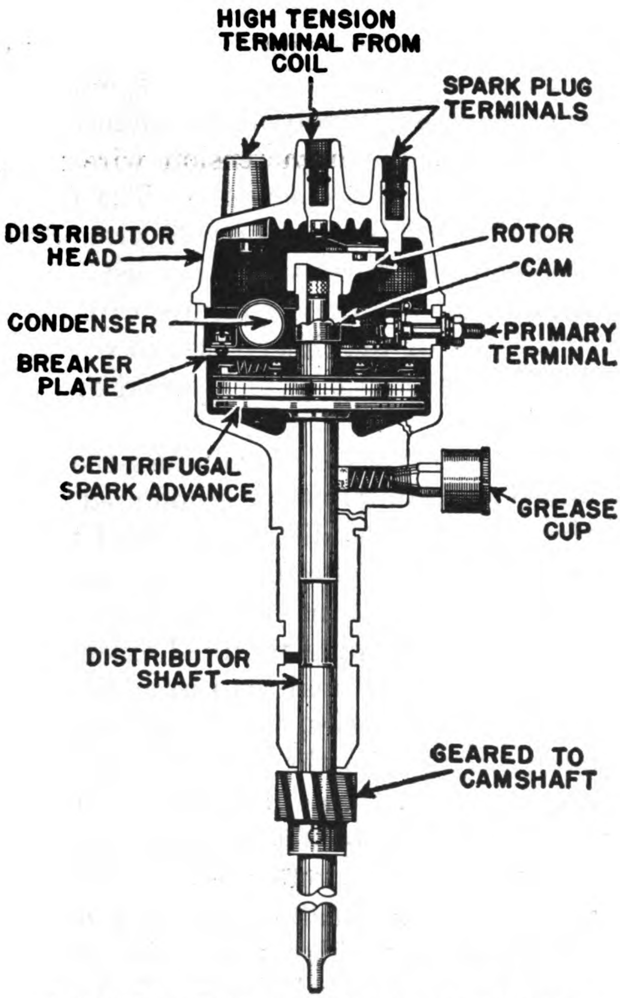



FIGURE 54.—Timer distributor in cross section.

(1) *Head.*—The distributor head has a center terminal which connects with the high tension terminal of the induction coil, and as many metal terminals equally spaced around it as there are spark plugs to fire. The head is usually molded of a highly resistant insulating material, such as bakelite or condensite, which is moisture-proof and possesses high insulating properties even under excessive heat. The terminals are of metal alloy molded in position, terminating on the under side either in the form of a button flush with the surface or in the form of a pin. The distributor head is usually held in place by two spring clips which snap on only when the head is in its proper position. Thus the head can be easily removed to inspect and adjust the rotor and breaker mechanism with no chance of replacing it incorrectly.

(2) *Rotor.*—The rotor or distributor arm is mounted on the upper end of the distributor shaft, on which the breaker cam is also located. The inside end of the rotor makes contact with the center terminal of the head, while the outside end in its rotation completes the circuit successively with the terminals leading to the spark plugs. The distributor may be considered as a revolving switch located in the secondary circuit which connects the high tension wire from the coil to the proper spark plug at the proper time. The distributing rotor must of necessity be well insulated to prevent grounding of the high tension current; consequently it is usually molded from an insulating material similar to that used in the distributor cap. It is usually designed to fit over the end of the timer shaft in one position only to prevent its installation in a position which would throw it out of time with the breaker.

*c. Types.*—There are two types of distributors, the gap type and the contact type, classified according to the method used in completing the circuit between the rotor and the distributor head terminals.

(1) *Gap.*—In the gap type, the rotor does not make actual contact with the spark plug terminals but instead simply passes close (approximately $\frac{1}{64}$ inch) to the spark plug terminal extensions in the head. The spark must then jump this small gap in addition to that of the spark plug, and as they are in series, the voltage required to overcome both gaps must be slightly greater than that for the plug alone.

(2) *Contact.*—In the contact type distributor, the end of the distributing rotor makes rubbing contact with the spark plug terminals in the head either by a metal button or by a carbon brush. In this type, the rubbing surface is usually composed of a hard rubber track with button segments molded flush with the inner surface. Hard rubber is used for the track instead of bakelite, as the latter

has a tendency to crack at the surface from the friction of the button or brush. The track must be kept clean and polished to prevent the rotor button from sticking and cutting the track.

*d. Operation.*—Each time a lobe of the breaker cam comes in contact with the breaker arm, the breaker points are separated and current is produced in the high tension winding by mutual induction of the coil. This high tension current is conducted to the central terminal of the distributor head by a highly insulated wire and from that point passes down to the rotor, from the end of which it jumps to one of the spark plug terminals and goes to the spark plug where it jumps the spark gap, completing the circuit through the ground.

*e. Drive.*—Since distributors have one terminal for each engine cylinder in single spark ignition and only one-half the cylinders fire each revolution, the rotor must turn at one-half the engine speed. The speed of the breaker cam may be made the same as that of the rotor by making the cam with as many lobes as the engine has cylinders. This makes it possible for the breaker cam and the distributor rotor to be mounted on the same shaft in battery ignition systems. This distributor shaft is geared to the cam shaft which drives it at half the engine speed.

*f. Lubrication.*—(1) A grease cup is usually provided on the side of the distributor to lubricate the distributor shaft. Grease is forced around the shaft by screwing in the cup. This cup should be screwed in one turn every 1,000 miles and refilled with grease when necessary. Lubricant fittings which are sometimes used, should be lubricated every 1,000 miles.

(2) A piece of felt saturated with oil is kept inside the hollow breaker cam to maintain a film of oil between the breaker cam and the distributor shaft so that the cam may be easily shifted. This felt oiler should be saturated with a few drops of oil every 1,000 miles.

(3) The breaker arm pivot and cam faces should be lubricated with a small amount of petrolatum every 6,000 miles or twice a year. On the vacuum type distributor with the breaker plate supported by ball bearings, the balls and races should be sparingly lubricated with light engine oil.

**38. Spark control.**—It is very essential that the time at which the spark occurs in the cylinder is changed according to engine speed, since it takes a definite length of time for a given fuel charge to burn regardless of the engine speed. In practically all battery ignition systems, the time of the spark with relation to the position

of the crankshaft and piston may be varied, while the engine is running, either by shifting the breaker mechanism around the cam or by shifting the cam with respect to the breaker mechanism. If the breaker arm is shifted in the direction of cam rotation, the contacts will open later with respect to the crankshaft position and the spark will be retarded. On the other hand, if the breaker arm is shifted against the direction of cam rotation, the contacts will open earlier with respect to the crankshaft position and the spark will be advanced. If the time of the spark is varied by shifting the

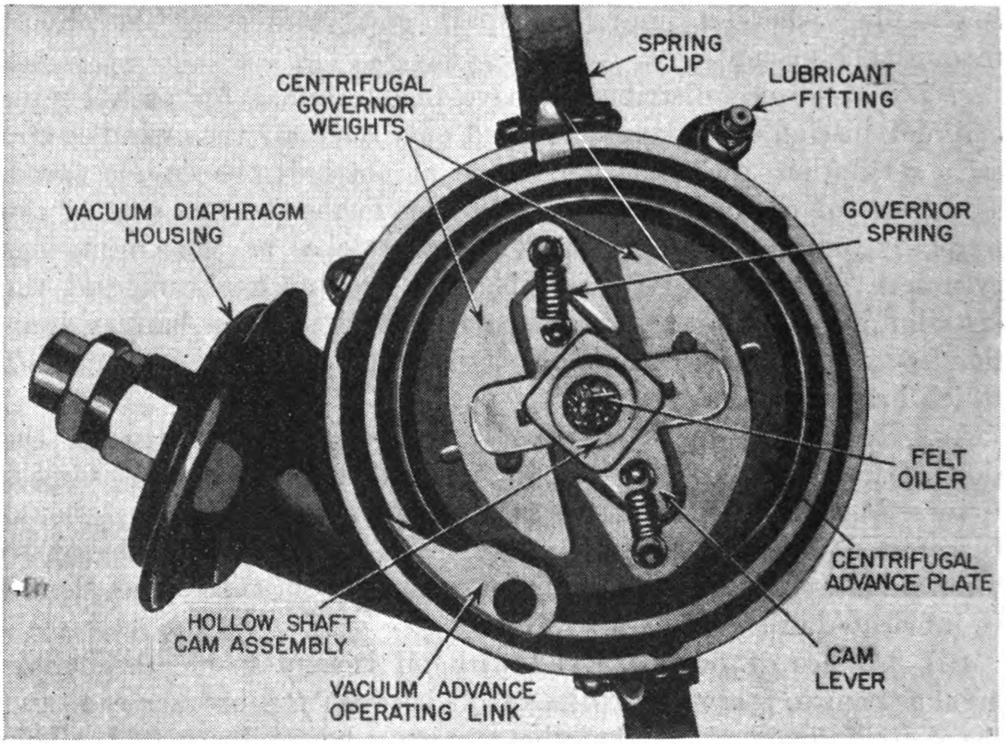



FIGURE 55.—Automatic spark advance mechanism operated by a centrifugal governor (breaker plate removed).

cam, the reverse will be true; that is, shifting the cam in the direction of normal rotation will make the contacts open earlier and thereby advance the spark, while shifting the cam against its normal rotation will make the contacts open later, thus retarding the spark.

*a. Manual.*—The spark can be advanced and retarded either manually by the driver through a spark control lever that is linked with the breaker housing, or automatically by centrifugal governors or vacuum devices, or both. Manual control requires skill and continuous attention on the part of the driver as the engine speed varies.

Owing to the great speed range of modern automobiles, manual control is practically obsolete.

*b. Automatic.*—The purpose of the automatic spark control is to relieve the driver of the responsibility of gaging the correct setting of the spark during normal driving speeds. Its use generally results in greater fuel economy and better operation of the engine at normal driving speeds.

*c. Centrifugal governor.*—The automatic centrifugal spark control mechanism consists of governor weights and springs mounted on a centrifugal advance plate located in the distributor body beneath the breaker plate (figs. 54 and 55). The centrifugal weights advance the breaker cam as the engine speed increases. The breaker cam and levers that rest against the tangs of the weights are contained as a unit on a hollow shaft assembly. As the weights fly outward (fig. 56) at increased speeds due to centrifugal force, they press against the cam levers so that the hollow shaft cam assembly is shifted forward in relation to the distributor shaft. This advances the spark automatically to the correct position in relation to the engine speed. The governor springs are calibrated to give a predetermined variation in spark advance for different engine speeds. As the speed decreases, the

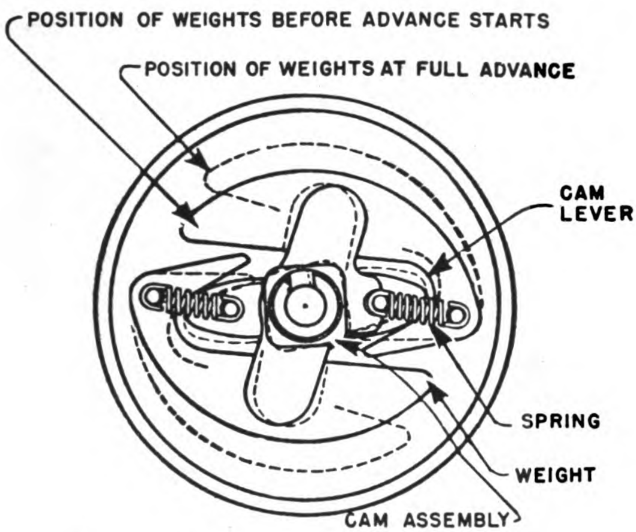



FIGURE 56.—Action of centrifugal weights.

weights are gradually returned to their slow speed position by the governor springs acting through the cam levers. This automatically retards the cam.

*d. Manual advance.*—In addition to the automatic advance, a manual advance is sometimes provided to control the time of spark under abnormal conditions. The hand advance need be used only

for starting, for differences in gasolines, with a wide open throttle at very low speeds, or at maximum speeds where a spark advance is required beyond that obtained by operation of the centrifugal governor.

*e. Vacuum.*—When an engine is suddenly accelerated or is working under a heavy load, the vacuum in the manifold decreases. This variable vacuum can be used to time the spark to meet the requirements of variable engine loads whereas the centrifugal governor reacts only to changes in speed. The centrifugal governor gives proper spark advance for average operating conditions only. The action of a

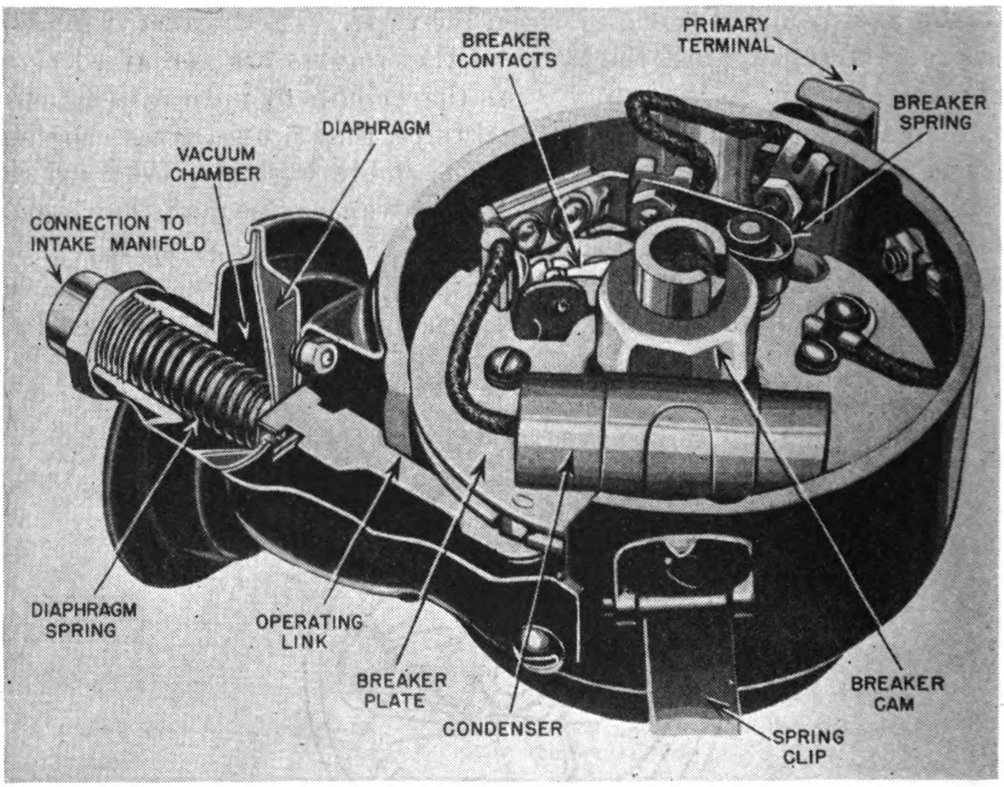



FIGURE 57.—Vacuum diaphragm automatic spark control mechanism.

vacuum unit combined with that of a centrifugal unit gives greater efficiency and better performance by meeting all conditions of engine operation.

(1) *Vacuum diaphragm.*—(*a*) A vacuum diaphragm assembly is usually mounted on the distributor housing and linked to the breaker plate to advance and retard the spark (fig. 57). The vacuum chamber next to the diaphragm is connected to the intake manifold so that changes in manifold vacuum will operate the diaphragm. When the

engine is not running, the breaker plate is in the retard position with the diaphragm held in its normal position by the diaphragm spring.

(*b*) A vacuum created in the intake manifold actuates the diaphragm against the spring pressure, shifting the breaker plate to an advanced position, thereby giving more spark advance than the centrifugal governor would alone. More power is obtained from the engine at low speeds as a result. On quick acceleration or open throttle operation, the vacuum in the manifold decreases, allowing the compressed diaphragm spring to return the breaker mechanism

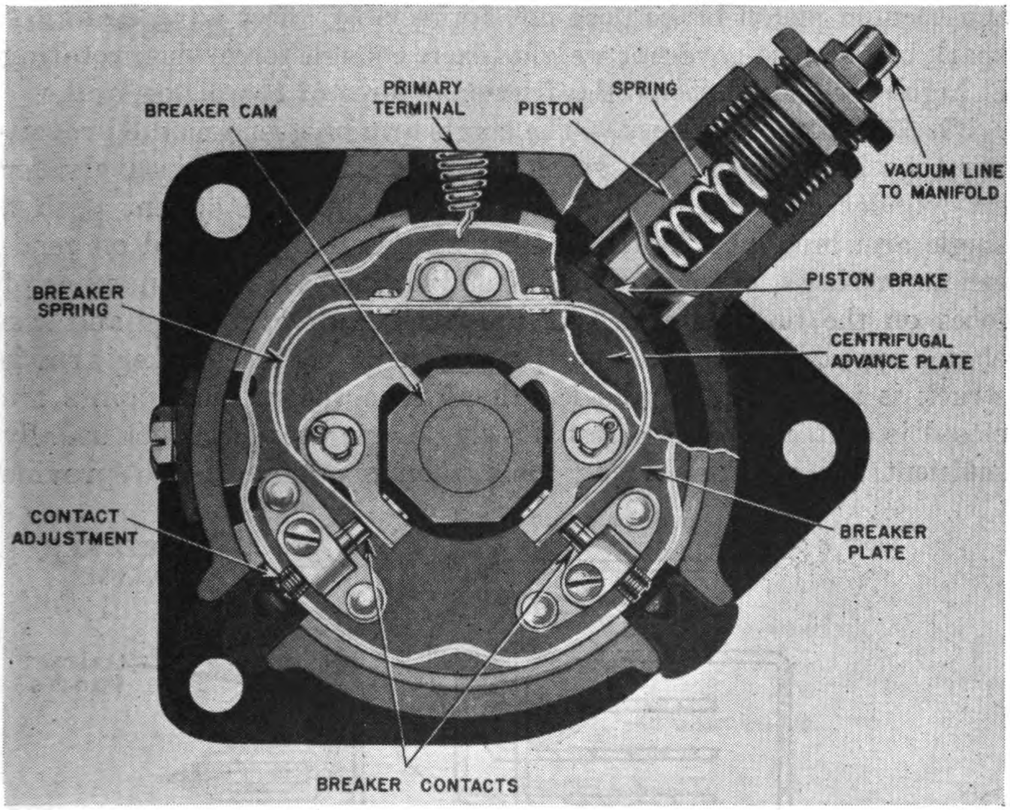



FIGURE 58.—Vacuum brake automatic spark control mechanism.

to the retarded position. This results in better performance of the engine under load and at high speeds. The breaker plate is supported by ball bearings to minimize the friction as it is shifted.

(2) *Vacuum brake.*—(*a*) Another method of controlling the spark advance is to have a piston brake, actuated by the vacuum in the intake manifold, on the centrifugal advance plate. Figure 58 shows this type of distributor mechanism.

(*b*) A high vacuum draws the piston brake away from the centrifugal advance plate, compressing the spring, and permitting the

centrifugal governor to control the spark advance. If the engine is suddenly accelerated, or operated under a heavy load, the vacuum decreases in the intake manifold, permitting the spring to push the piston toward the centrifugal advance plate and engaging the piston brake. The friction imposed upon the centrifugal advance plate exerts a force counter to the centrifugal force of the weights so that the weights move inward, retarding the cam. As soon as the vacuum in the intake manifold increases, the vacuum piston brake is pulled back, allowing the governor weights to fly out and advance the timing.

(*c*) When the vacuum drops to a low point at high engine speeds, the vacuum piston brake does not appreciably affect advance of the spark because the governor weights exert enough force when rotating at high speed to overcome the frictional force of the piston brake.

**39. Multiple breakers.**—The single arm breaker was the prevailing type in early ignition systems. It is still used extensively for six-cylinder engines. Figure 59 shows an ignition system with a single arm breaker. As the number of cylinders increased on modern automobiles, it meant a corresponding increase in the number of lobes on the breaker cam. As the number of cam lobes and the engine speed is increased, the speed with which the breaker arm is struck is increased and the length of time the breaker points are closed is decreased. As a result a single arm breaker is not usually sufficient for engines having more than six cylinders to provide

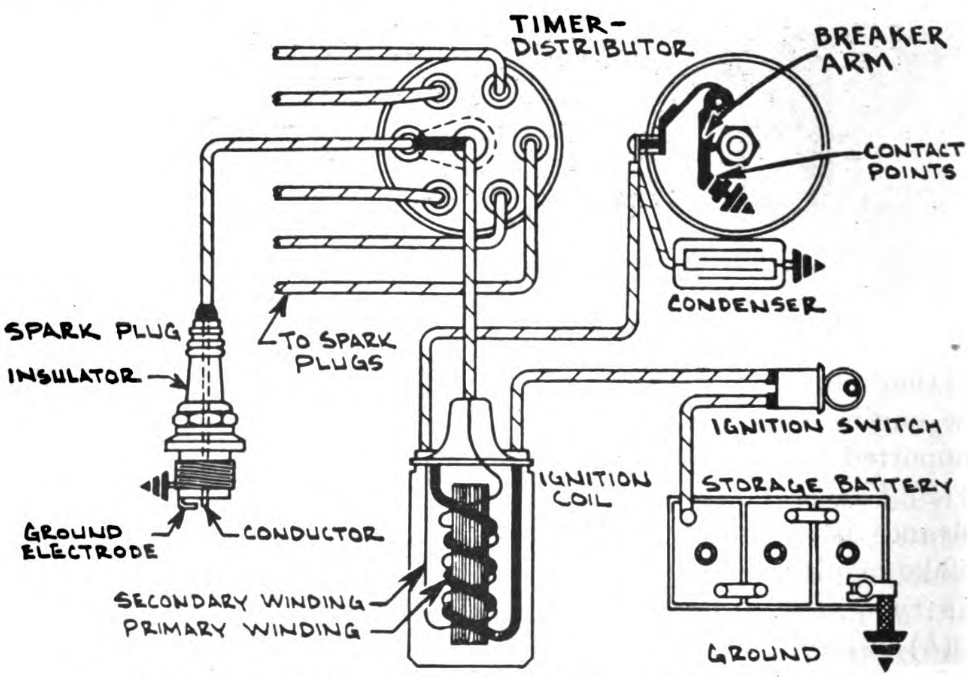



FIGURE 59.—Ignition system with single arm breaker (six-cylinder engine).

satisfactory magnetization of the coil. When the breaker arm is struck very rapidly by the cam, as it is in high speed engines, it may develop a tendency to bounce or chatter. Hence two arm breakers are introduced to give satisfactory ignition. Multiple breakers are operated by two methods; one in which the two breakers operate in parallel with each other in the same circuit, and one in which each breaker opens a separate circuit.

*a. Parallel operation.*—To counteract the bounce or chatter of the breaker arm and to prevent overload of the contact points, two breakers can be connected in parallel and adjusted to open at the same time (fig. 60). If one pair of contacts has a tendency to bounce open at high speed, it is probable that the other pair will not bounce at exactly the same instant, and therefore the circuit will be closed much more positively than it would be with only one pair of contacts. The breaker arms also can be connected in parallel but made to operate progressively; that is, they are so set with respect to the cam lobes that one arm opens its contacts slightly before the other. The circuit is not actually broken until the second set of contacts open. Both sets of contacts are open for a shorter period of time than they are in simultaneous operation. This allows the ignition coil a slightly longer period of time in which to build up. The breakers (fig. 58) are arranged for progressive parallel operation.

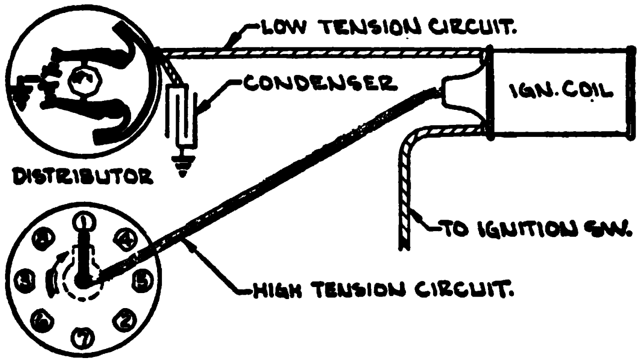



FIGURE 60.—Two breaker arms arranged for parallel operation (eight-cylinder engine).

*b. Alternate operation.*—This is another arrangement which greatly increases the time of contact and allows better magnetization of the coil. The two pairs of contacts still operate electrically in parallel but use a cam with only half as many lobes as there are cylinders to be fired. The breakers are so arranged around the cam that one pair of contacts will close almost immediately after the other pair has opened. Thus the two sets of breaker contacts almost overlap each other's movements so that there is no waste of time.

Shortly after one pair of contacts opens the circuit, the other pair of contacts closes it so that the coil can start to build up at once in preparation for the next spark. One set of contacts operates for half the cylinders and the other set for the other half. Figure 61 shows the breaker arms set for alternate operation.

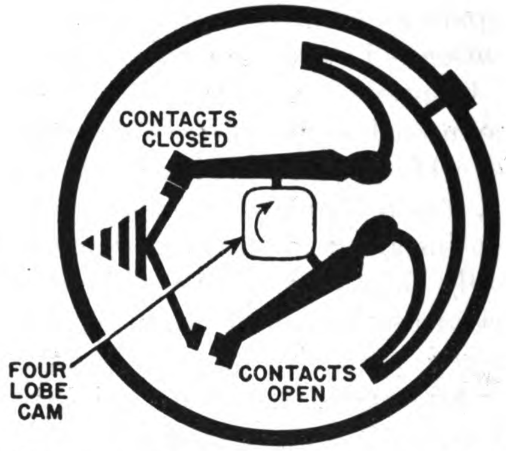



FIGURE 61.—Two breaker arms arranged for alternate operation (eight-cylinder engine).

*c. Two-circuit operation.*—(1) Another breaker arrangement, very similar in appearance to that used for alternate operation, is used with two separate coils for firing a large number of spark plugs. The breaker contacts operate alternately but have no electrical connection between them except their common ground. In effect, this ignition interrupter permits two separate ignition systems, one system operating for one-half of the cylinders and the other system for the other half. Here the relation between the two sets of contacts is one of timing only so that each will operate at the correct instant for the cylinders it serves.

(2) The distributor must take care of the two circuits. Figure 62 shows the usual design of an integral construction distributor for the two circuits. The high tension lead from one coil enters the center of the distributor head at terminal *A* while the high tension lead from the other coil enters at another terminal *B*, which is connected to a small ring that surrounds the central terminal. Two separate segments are molded within a double arm rotor, each one in contact with one of the high tension terminals. One rotor segment completes its circuit to alternate spark-plug terminals in the distributor cap, the other rotor segment taking the intervening terminals. Thus there are two separate secondary circuits, *A* and *B*, each one furnishing current to half the spark plugs. The sparks from each coil are

produced in exactly the same way as they are in a single system since each coil has its own set of breaker contact points.

(3) Two-circuit operation is particularly adaptable to **V**-type engines, with each set of contacts taking care of one bank of cylin-

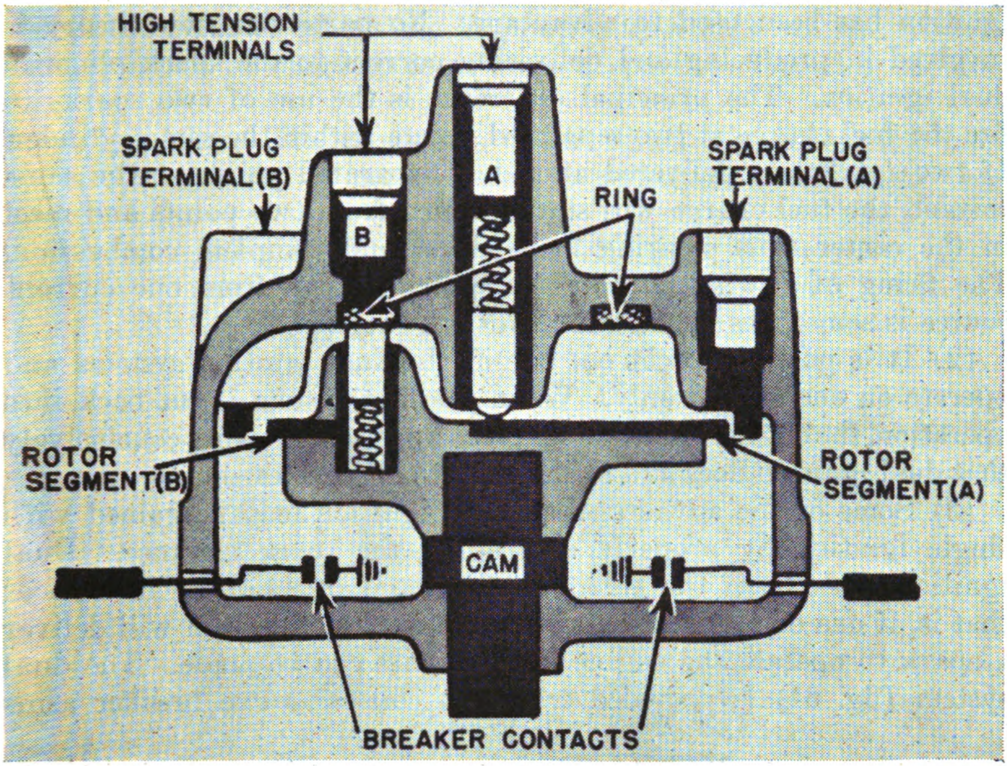



FIGURE 62.—Two-circuit distributor construction.

ders. Figure 63 shows an arrangement for a **V**-12 engine. Since each set of breaker contacts is electrically independent of each other, the breakers require synchronizing for proper operation. On

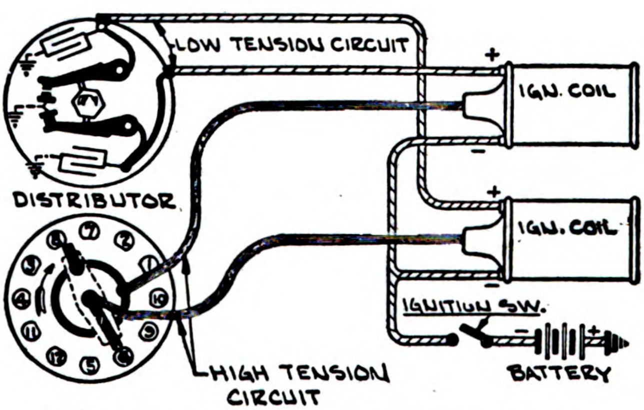



FIGURE 63.—Two-circuit system (**V**-12 engine).

some V-type engines, the two breaker arms open at irregular intervals and the manufacturer's specifications should be checked before attempting to adjust the contact points.

*d. Dual (twin) ignition.*—(1) Practically all automobiles have single ignition (one spark plug in each cylinder) although dual ignition has been used to advantage. No particular new theory is involved in producing and delivering current to the spark plugs in dual ignition. The principal difference is the use of two sparks to fire the fuel charge at two separated points within the same cylinder. If two sparks are delivered at widely separated points at the same instant, the fuel charge will start to burn from two points and meet in the center thus securing more rapid and complete combustion. The firing of two spark plugs in each cylinder from one current source is sometimes called twin ignition.

(2) It is possible to cut out one of the dual ignition systems and operate on one system only. When the first system is cut back into operation, the engine immediately picks up speed, showing conclusively that dual ignition does add to the performance of an engine.

(3) Some of the advantages of dual ignition may be gained with single ignition by properly controlling the spark advance. Dual ignition does have the distinct advantage of ignition insurance; that is, if one of the ignition systems fails, the other still will deliver a spark to operate the engine until repairs can be made. The dual system (fig. 64) is provided with two coils and two breaker arms

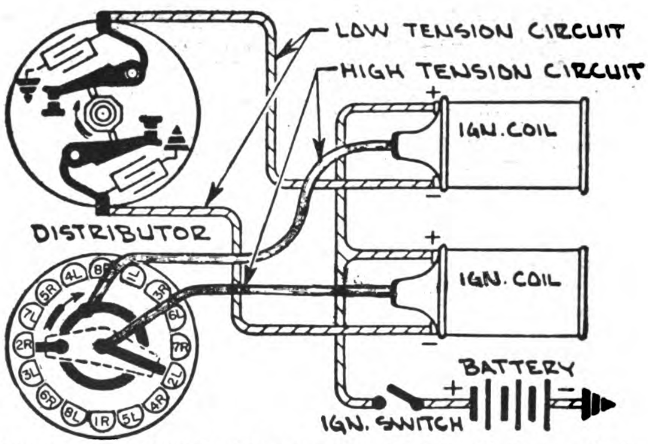


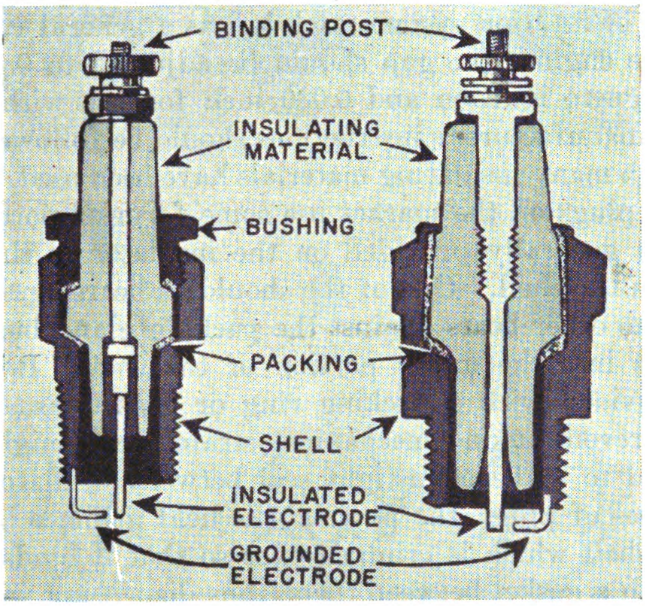

FIGURE 64.—Dual ignition system (eight-cylinder engine).

operating on two circuits to supply sparks to two sets of spark plugs. To obtain the full advantage of dual ignition, the breaker contacts must be synchronized to fire two sparks simultaneously in each cylinder. The rotor segments will then deliver sparks to two opposite terminals in the distributor head which are connected on two spark

plugs within the same cylinder. Each rotor segment fires alternate terminals around the head; one segment firing the spark plugs on the right side of the cylinders, and the other segment firing the spark plugs on the left side of the cylinders.

**40. Spark plugs.**—The spark plug provides suitable electrodes inside the cylinder which can be jumped by a high voltage from an induction coil or magneto to produce a spark for igniting the fuel mixture.

*a. Operation.*—The conditions under which the spark plug must operate are severe. It must be able to withstand an electrical pres-




① Insulator held in place by bushing. ② Insulator sealed in position.

FIGURE 65.—Sectional views of typical spark plugs.

sure of 15,000 to 30,000 volts under high compression pressures and temperatures, thirty or thirty-five times per second when the engine is running at high speed. The pressure in the combustion chamber from explosion of the fuel charge tends to force the plug from the cylinder head. At the same time the heat of combustion, which in high compression engines may reach a maximum of 3,000° F. or more, tends to burn and distort the electrodes, which would change the spark gap setting. In addition, the surfaces of the insulator tend to become overheated and burned, which materially decreases the resistance of the insulator and usually causes electrical leakage around the plug. Internal strains due to sudden changes in temperature tend to crack the insulator. It is, therefore, of highest importance that correct design and materials enter into the construction of the spark plug.

*b. Construction.*—Typical spark plug construction is shown in figure 65. The two electrodes are insulated from each other, the center one being surrounded with insulating material, usually porcelain or mica, while the other is attached to the steel shell which is grounded when the plug is screwed into the cylinder head.

(1) As shown in figure 65, the principal parts of the spark plug are the steel shell which is threaded so it can be screwed into the cylinder head; the insulating material, which confines the electrical current to the spark gap; and the electrodes, or sparking points, which should form a gap of approximately 0.025 inch to 0.040 inch. The best gap size will vary somewhat with the engine compression and the type of ignition system used, but as a general rule, for most motor vehicle engines the gap should be adjusted to 0.025 inch for use with magneto ignition and 0.030 inch for use with battery ignition. The manufacturer's instructions should be followed.

(2) Though many insulating materials have been used, the majority of the spark plugs on the market use some form of porcelain. Two shoulders are generally provided on the insulator so that it can be held firmly in the shell. One of the shoulders bears against the shell seat, while the other bears against the packing gland bushing or nut which screws into the upper portion of the shell. Both insulator seats are provided with a packing ring or gasket, usually made of copper, to prevent undue mechanical strains that might crack the insulator, and to make a gastight seal between insulator and shell. In some makes of plugs, the porcelain is held in place by the upper edge of the shell which is crimped over so that it binds against the insulator, with a gasket between them, thus dispensing with the bushing. This construction which is widely used simplies the plug design.

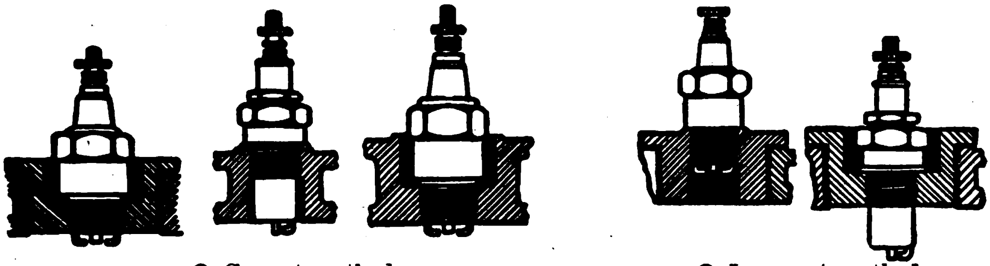
(3) Practically all plugs now on the market have steel shells; brass and other metals have been tried, but with little success. Steel not only has high tensile strength but its coefficient of expansion is practically the same as that of the cylinder head.

(4) The thickness of the cylinder heads through which the plugs are inserted may vary. The spark plug is usually fitted so that the electrodes protrude just past the combustion chamber wall (fig. 66). However, this varies in different makes of engines.

(5) High compression pressures and increased speeds, which result in higher temperatures, necessitate the use of a plug which will dissipate heat very rapidly. The extent to which a plug will dissipate heat depends on the length of insulation exposed to the combustion gases. Hence, for engines which develop a lot of heat, a plug with short insulation, or a cold plug, should be used. For low compres-

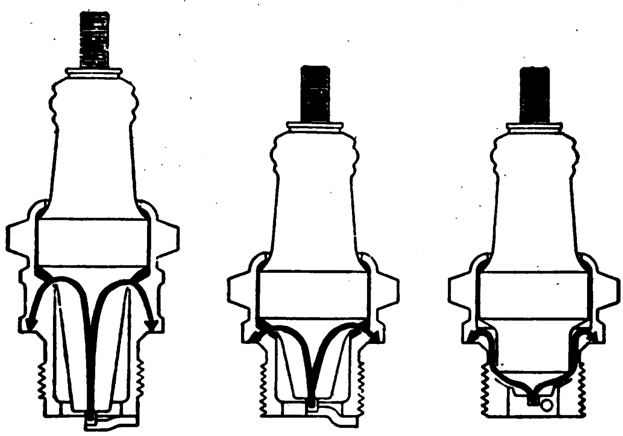
sion or slow speed engines a plug with long insulation, or a hot plug, should be used. Figure 67 shows three plugs of various heat ranges and illustrates the path of heat conduction.

(6) The heat characteristics of an engine are not the only things that must be considered in the selection of a spark plug. The conditions under which automobiles, trucks, and buses are operated have



① Correct method. ② Incorrect method.

FIGURE 66.—Fitting spark plugs.



① Hot. ② Medium. ③ Cold.

FIGURE 67.—Path of heat conduction in spark plugs of different heat ranges.

an important bearing upon the selection. Exceptionally severe service, such as continuous runs in mountainous country with heavy loads and frequent shifts into low gear, or running at high speeds for long distances will require a plug colder than that used for ordinary service.

**41. Ignition timing.**—Timing an ignition system consists of adjusting it to produce a spark in each engine cylinder at the proper time so it will deliver the maximum power. Correct timing requires a setting that will allow proper control by the advance mechanism. Since distributors are designed for the particular firing order of an engine, it is necessary in ignition systems with a single breaker to time the ignition for only one cylinder. The other cylinders will be

timed automatically from this setting. It is common practice to use No. 1 cylinder for this purpose. Where multiple breakers are used, each set of contacts must be timed for their respective cylinders. This is usually accomplished by first setting one set of contacts to the proper timing mark and then setting the other contacts in proper relation. Before timing the ignition, the contact points should be clean and adjusted for the proper gap.

*a. Cranking method.*—(1) Most engine manufacturers provide some form of marking on either the flywheel or on the crankshaft damper to serve as identification marks when timing the ignition. These marks are set to a fixed pointer. Marks provided on the flywheel can be seen through an opening cut into the flywheel housing. Two markings are provided; one for top dead center (usually marked DC or TDC) and the other for ignition timing (usually marked IGN) (fig. 68). When marks are provided on the crankshaft damper, they are indicated in degrees before and after top dead center, zero being top dead center (fig. 69).

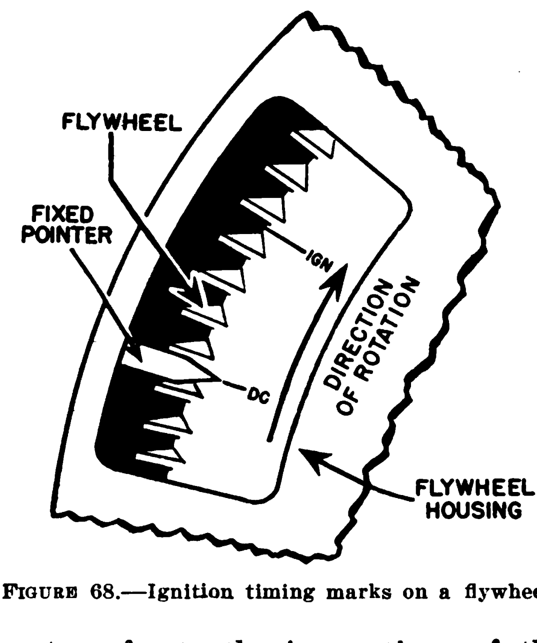



FIGURE 68.—Ignition timing marks on a flywheel.

It is necessary to refer to the instructions of the engine manufacturer to know just what timing point is recommended when markings are in degrees. The recommendation is either so many degrees before or after top dead center. If the engine has no markings, a piston position gage can be held in position and inserted through the spark plug hole of No. 1 cylinder to secure accurate results. In the latter case, the manufacturer's timing recommendations in thousandths of an inch of piston travel before or after top dead center must be

referred to. Some engines have a plug over No. 6 or No. 8 cylinder which can be removed to insert gage for timing purposes.

(2) If a manual spark advance is provided, it should be set usually just a little before the fully retarded position. The manufacturer's instructions should be followed. When setting the timing of an engine to the timing marks, the engine should be cranked until No. 1

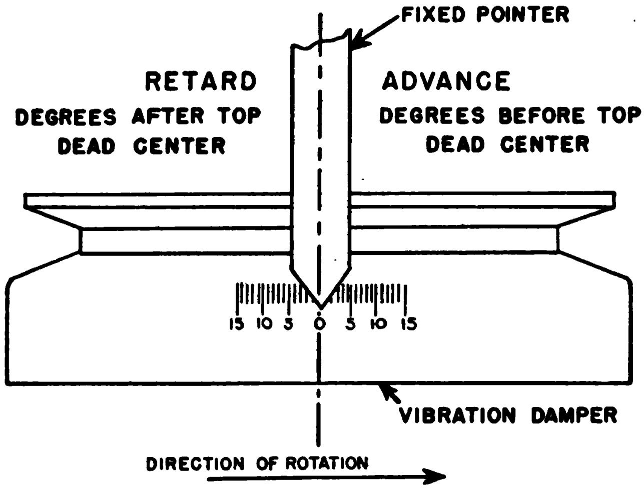



FIGURE 69.—Ignition timing marks on a crankshaft vibration damper.

piston is coming up on its compression stroke and then stopped at the correct timing mark. The timing mark should always be approached with the engine cranked in its normal direction of rotation (usually clockwise) so that all backlash of timing chains and gears will be eliminated. If the timing mark is passed, the engine must be turned back and the timing mark again approached from the normal direction of rotation. The distributor head should be removed to note the direction in which the distributor shaft rotates when the engine is cranked.

(3) With the No. 1 piston at correct position for timing, the distributor rotor should be at the terminal that connects with No. 1 spark plug, and the breaker contacts should just begin to separate. To accomplish this, the distributor cam should be loosened so that it can be turned on the shaft. If the cam is of the fixed type, the distributor housing should be loosened. Since the distributor rotor fits on the cam in only one position, the cam or housing should be turned so that the rotor is adjacent to one of the terminals. This can easily be determined by holding the head in proper position above the rotor. This terminal to which the rotor is adjacent should be connected to the spark plug in No. 1 cylinder.

(4) The cam should be turned opposite to its direction of normal rotation (to take up the backlash in the driving gears) until the breaker contact points just begin to close and then tightened to its shaft (fig. 70). If the distributor housing is loosened, it should be turned opposite to the direction in which the cam is driven until the contact points begin to open and then clamped in this position. Determining the closing or opening of the contact points by eye is usually not accurate enough. Correct timing can be accomplished by noting when the dash ammeter reading jumps or by connecting a small electric test lamp across the contact points. If the terminals of the test lamp are connected to the contact point terminals, the lamp will go out when the contact points close and go on when the contact points open because the circuit is then completed through the test lamp. When the contact points are properly timed, the distributor terminals must be connected in proper sequence to the spark plugs according to the firing order of the engine. Firing orders are usually stamped on the engine in a prominent location.

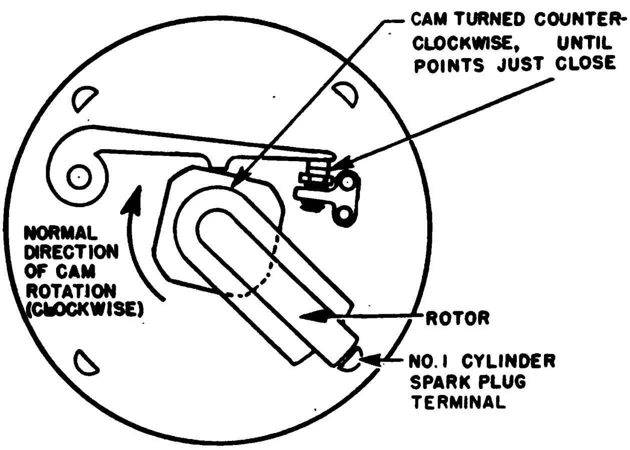



FIGURE 70.—Timing the ignition system by rotating the breaker cam.

*b. Neon timing light method.*—(1) This is a very effective and quick method for ignition timing. The timing mark on the flywheel and the pointer should be made easily visible by covering them with white lacquer or chalk. Sometimes a hole is provided in the flywheel for a bright steel ball, which lines up with the timing pointer at the center of the flywheel housing opening when the distributor breaker points should open. One terminal of the neon timing light is connected to the No. 1 spark plug and the other terminal to a good ground. The neon timing light is held just in front of the opening so that the flywheel is illuminated as shown in figure 71.

(2) If the engine is equipped with an octane selector (which is a spark advance adjustment), set the selector at zero. As the engine runs on its own power, the make-and-break of the contact points lights the neon timing light intermittently, producing a stroboscopic effect as it illuminates the timing marks. The stroboscopic effect makes the mark or ball on the flywheel appear to stand still in relation to the pointer. The distributor clamp should be loosened so that the distributor can be rotated until the mark or ball remains exactly in line

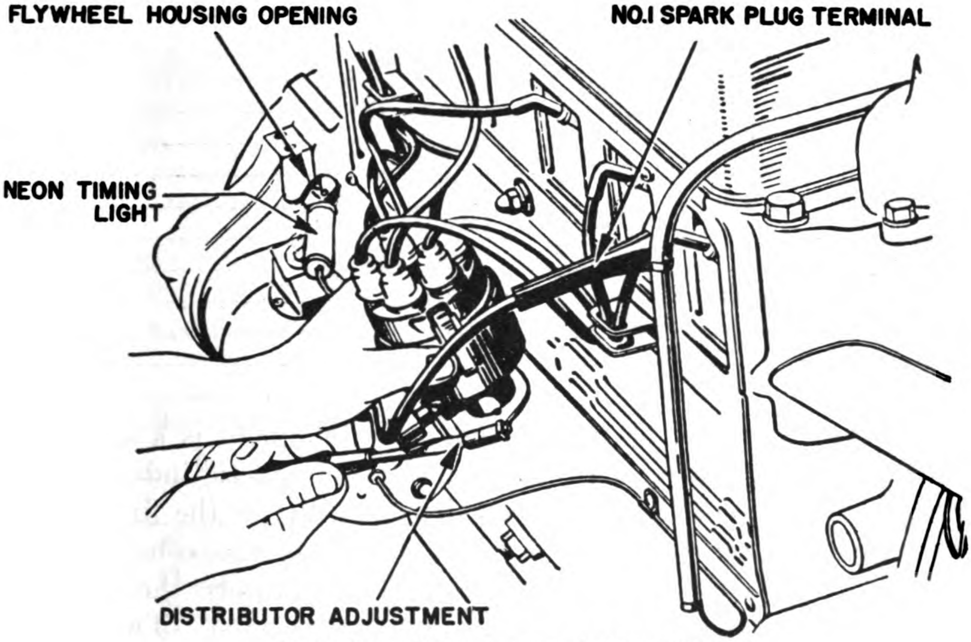



FIGURE 71.—Using a neon timing light.

with the pointer. When this adjustment is obtained, the distributor can be locked in position with the assurance that the timing is correct.

*c. Synchronizing breaker contacts.*—Multiple breakers must be synchronized so that the breaker contacts operate at the proper time with respect to each other. In some cases, this may be at the same time or it may be at a definite interval, which is expressed in angular rotation of the breaker cam. When the breaker contacts are to operate at the same time, the two breaker arms can each be adjusted with the No. 1 piston at the timing mark. When there is to be a definite interval between the breaker contact openings, one breaker should be adjusted so that its contacts open at the proper timing position when the corresponding rotor segment is opposite the terminal for the No. 1 cylinder and the other breaker arm adjusted so that its contacts open when the cam has rotated a specified distance in degrees. Sometimes a timing mark is provided for each set of contacts. Each

breaker can then be adjusted to its own timing mark when the proper cylinder for each breaker is on its compression stroke. The angle through which the crankshaft turns between one firing point and the next determines the angle of cam interval, remembering that the cam turns at one-half crankshaft speed.

## SECTION V

## MAGNETO IGNITION



**42. Classification of magnetos.**—The magneto is a device for mechanically generating electricity by electromagnetic induction. It serves as a source of ignition when dependability is the first consideration, as in aircraft engine service. The magneto consists essentially of two parts; a permanent magnet to supply the magnetic field, and a winding in which the current is generated. Two general types of magneto construction are used, depending on whether the winding is revolving or stationary; the armature wound and the inductor types.

*a. Armature wound.*—(1) In this type of magneto construction the winding is wound on an armature which revolves within a magnetic field produced by stationary permanent magnets mounted on the magneto frame. Current is generated by the rotating winding cutting the magnetic field.

(2) The armature core, made of stampings or laminations of soft iron, is generally of the H or shuttle type (fig. 72). The core is wound with a number of turns of insulated wire which form a coil.

(3) It is necessary to provide either terminal contact buttons or slip rings (fig. 73) to carry the current from the rotating coil to a collector brush. In order to simplify the construction of the magneto, only one contact button or slip ring is used, which is thoroughly insulated and connected to one end of the winding. The

other end of the winding is grounded to the armature core, and the core is grounded through a brush, which makes positive ground connection between the rotating armature and the frame of the magneto.

(4) It is essential that the grounding brush makes a good connection, otherwise the current will flow through the bearings of the

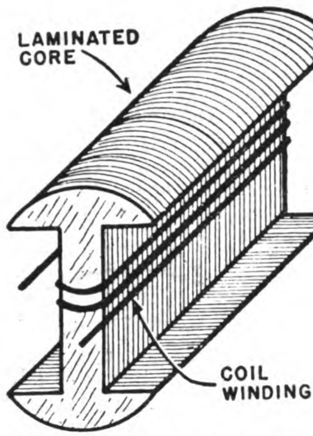



FIGURE 72.—Laminated core of a magneto armature showing a few turns of the winding.

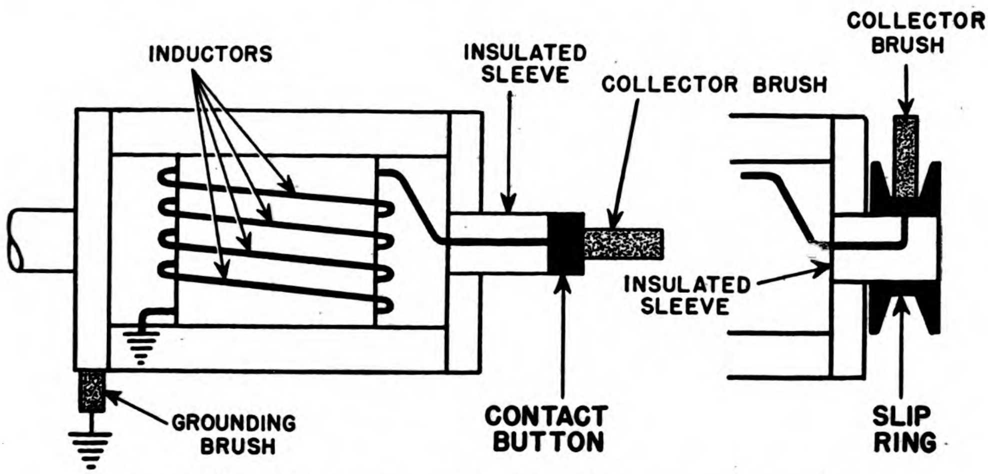



FIGURE 73.—Methods of carrying current from a magneto armature.

magneto which is not desirable, particularly with ball bearings, because oil and grease are poor conductors. Any slight sparking that might occur in the bearings will carbonize the oil and pit the bearings, ruining the magneto by changing the alinement of the armature.

*b. Inductor.*—(1) The winding in this type of magneto is stationary. A rotor is used to direct the magnetic field through the winding, first in one direction, then in the other. With this type of magneto, the current is induced in the winding by the changing magnetic field.

(2) Brushes and slip rings are not required in the inductor type magneto since the coil is stationary and the connection can be made

directly to the coil. This permits a simpler construction than is possible with armature wound magnetos.

(3) Although there are a number of different designs of both the armature wound and the inductor type magnetos, the principles involved in each are practically the same. Both armature wound and inductor magnetos can be made for low tension and high tension operation. The construction of an inductor magneto is discussed in paragraph 49.

**43. Magneto magnets.**—*a.* A horseshoe magnet usually forms the frame for the magneto. Soft iron pole pieces are attached to the poles of the steel magnet (fig. 74). The inner ends of these pole pieces

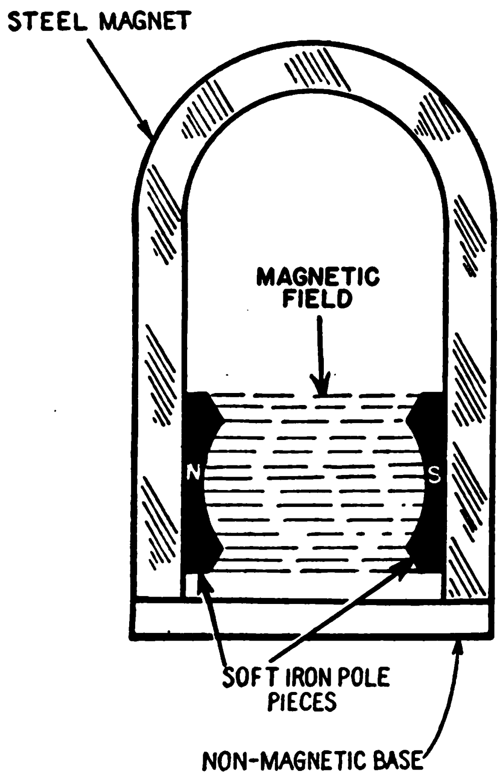



FIGURE 74.—Magneto magnet.

are circular and project far enough inward so that there will be very little air gap or clearance between the pole pieces and the rotating armature. Since the magneto is usually attached to steel or cast iron, a base of nonmagnetic material is placed under the ends of the magnet to prevent the magnetic field between the poles from being diverted by the metal on which the magneto is mounted.

*b.* The retention of magnetism by steel is a very curious and interesting property. It is found that a much stronger magnet is obtained,

weight for weight, by putting two or more magnets together than by using a single large magnet. To accumulate the magnetism of separate magnets, all the north poles are placed together and all the south poles together. An easy way to tell if like poles are together when placing the magnets on a magneto, is to place the magnets so that adjacent poles of the individual magnets repel each other.

*c.* The advantage of a permanent magnet in a magneto is that the magnetic field is of a high intensity at very slow magneto speeds so that a good spark is produced. At the same time, the magnetic field does

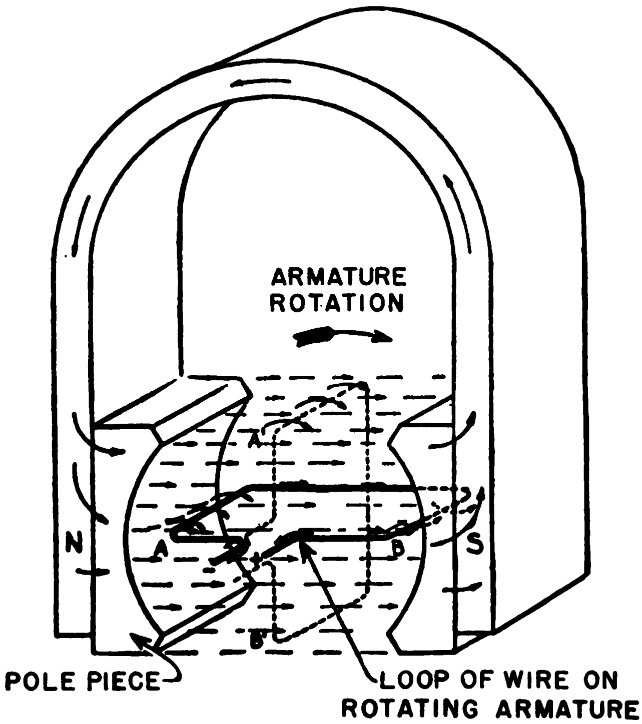



FIGURE 75.—Induced current in a loop of wire.

not increase with speed so that excessive voltages will not be produced at high speeds and burn out the winding. An extremely hard steel, usually chrome or tungsten steel, is generally used for the magnets.

**44. Generation of current.**—*a.* It has been found that an electric current will be generated in a wire if the wire is moved across the magnetic field between the poles of a magnet. If the wire is then moved across the magnetic field in the opposite direction, the generated current flows in the reverse direction.

*b.* The wire of the magneto coil, in the shape of a rectangle or a loop, rotates on the armature between the pole pieces of the magnet (fig 75). While one side of the loop of wire *A* (fig. 75), is going up through the

magnetic field, the other side, *B*, is going down. By use of the right hand rule, it will be seen that current is induced to flow one way on one side of the loop and the other way on the other side, so that the electrical pressures induced are added and cause the current to flow around the loop. When the loop reaches a position in its rotation where it is vertical and at right angles to the magnetic field, the wire does not cut any lines of force in the magnetic field, but travels with them. Hence, no pressure or voltage is produced when the loop reaches this point. After passing the vertical position, the sides of the loop cut the magnetic lines of force in the opposite direction. That is, the side that was going up against the lines of force now goes down and the one that was going down now goes up. This causes an induced voltage in the opposite direction and the current through the loop of wire is reversed; that is, the flow of current in a loop of wire revolving in a magnetic field is alternating in direction. All the loops in a magneto winding act similarly. The total magneto voltage is an accumulation of the individual loop voltages.

*c.* To differentiate between the directions of induced voltage, the voltage induced in one direction is called positive (+) voltage, and that induced in the opposite direction, negative (−) voltage. The cycle of induced voltage is represented graphically in figure 76. The corresponding positions of the loops during a revolution of the armature are shown. Starting with no voltage induced in the armature at the start of the cycle, the loops are perpendicular to the lines of force. After one-quarter revolution (90°) of the armature, the loops are parallel to the magnetic lines of force. The induced voltage then has a maximum value in one direction (say positive). At one-half a revolution (180°), the loops are again perpendicular to the magnetic field so that the voltage is again zero. The voltage reaches a maximum again, but in a negative direction, when the loops are parallel to the lines of force after three-quarters (270°) revolution. After a full revolution (360°), the armature is at the same position it was when it started the cycle and no voltage is induced. Thus it is seen that the two-pole magneto generates two voltage peaks for each complete revolution.

**45. Low tension magneto.**—*a.* A low tension magneto is one which delivers current at a low voltage. The armature has a single winding with about 150 to 200 turns of fairly large insulated wire similar to that placed on a primary induction coil. The armature is driven by the engine through gears and timed so that the spark will occur when the induced voltage is at or near a maximum.

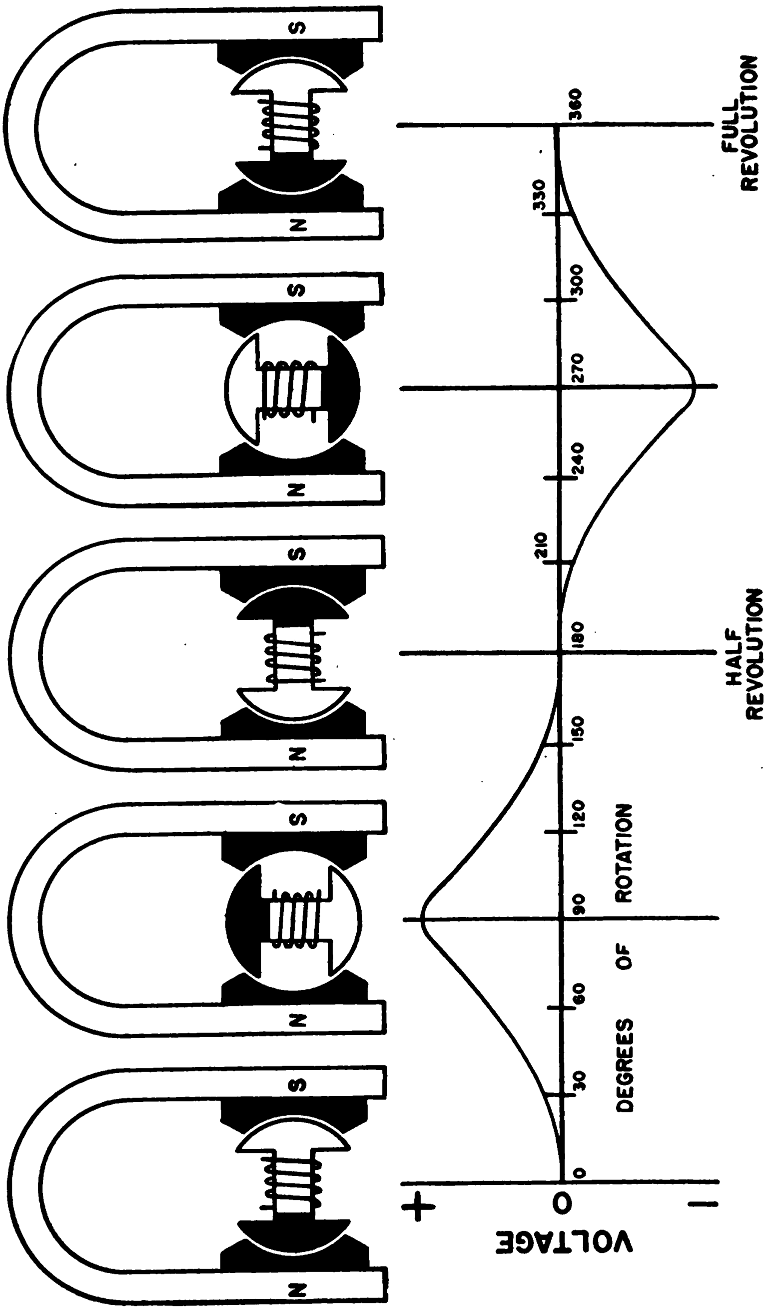



FIGURE 76.—Value of voltage induced during a full revolution of a magneto.

*b*. In make-and-break battery ignition, a primary or self-induction coil is necessary. However, the winding of a magneto armature has sufficient self-induction to supply a good spark so an outside coil is not necessary with make-and-break magneto ignition. When a low tension magneto is used for jump spark ignition, an outside induction coil is necessary to increase the voltage.

**46. High tension magneto.**—*a*. Under high tension magnetos are included all magnetos which generate directly in the magneto winding a current of sufficiently high voltage for jump spark ignition without the aid of a separate induction coil. High tension magnetos contain both a primary and a secondary winding similar to the winding of an induction coil instead of the usual single winding found in low tension magnetos. A high tension magneto also incorporates an interrupter, distributor, and condenser, so that the magneto contains within itself all the essentials of a complete ignition system, the only necessary outside parts being spark plugs and a magneto controlling or ignition switch. This applies to both the armature wound and the inductor magneto.

*b*. The primary circuit of a high tension magneto consists of a primary winding on a stationary or rotating armature, a condenser, and an interrupter. The secondary circuit consists of a secondary winding located on the armature of the magneto, a distributor, and the cables leading to each of the spark plugs (fig. 77). One side of each circuit is grounded; that is, the current returns through the metal of the magneto in the primary circuit and through that of the engine and the magneto in the secondary.

*c*. One end of the primary winding is grounded through a grounding brush while the other end is brought out to the interrupter through a slip ring or contact button. It is customary to build the interrupter on an extension of the armature shaft although in illustrations it is shown just below the magneto for the sake of clearness.

*d*. The distributor, conveniently mounted in the upper portion of the magneto, is driven by gearing it to the armature shaft. The center terminal is connected to the high tension end of the secondary winding. From the distributor, wires go out to the spark plugs.

**47. Interrupters.**—The purpose of the interrupter is to open the primary circuit when the armature reaches a peak voltage position. To accomplish this, the interrupter is constructed in various forms. With an armature wound magneto, the breaker contacts usually revolve with the armature. With an inductor magneto, the breaker contacts remain stationary with the winding. This practice is followed so that simple connections can be made from the primary winding to the

breaker contacts in either type of magneto. Regardless of detailed differences in their construction or design, all high tension magnetos operate on the same principles.

*a. For armature wound magneto.*—(1) This type of interrupter usually consists of a stationary contact and a movable contact on one arm of a bell crank breaker arm (fig. 78). Both of these parts are mounted on a breaker disk which is securely fastened to the armature shaft and rotates with it. The stationary contact is insulated from the

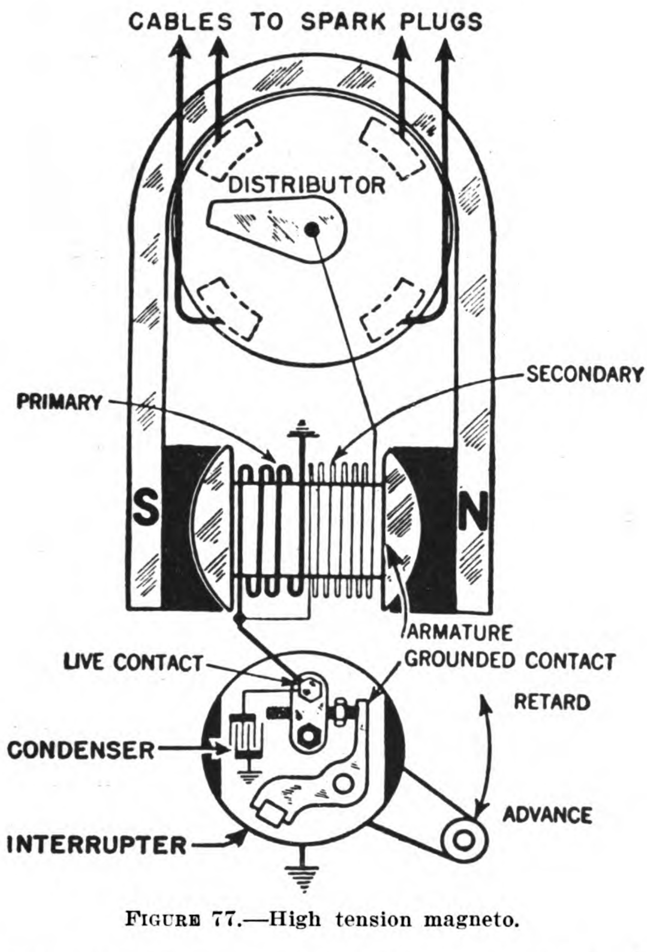



FIGURE 77.—High tension magneto.

disk and connected to one end of the primary winding. The movable contact is grounded to the breaker disk which is grounded to the frame of the magneto by a carbon brush. A spring on the movable arm keeps the contact points together.

(2) In each revolution of the armature in the ordinary two-pole magneto, there are two voltage peaks, one a positive peak and the other a negative peak. Taking advantage of these two voltage peaks, two sparks can be produced for each revolution of the armature. Two

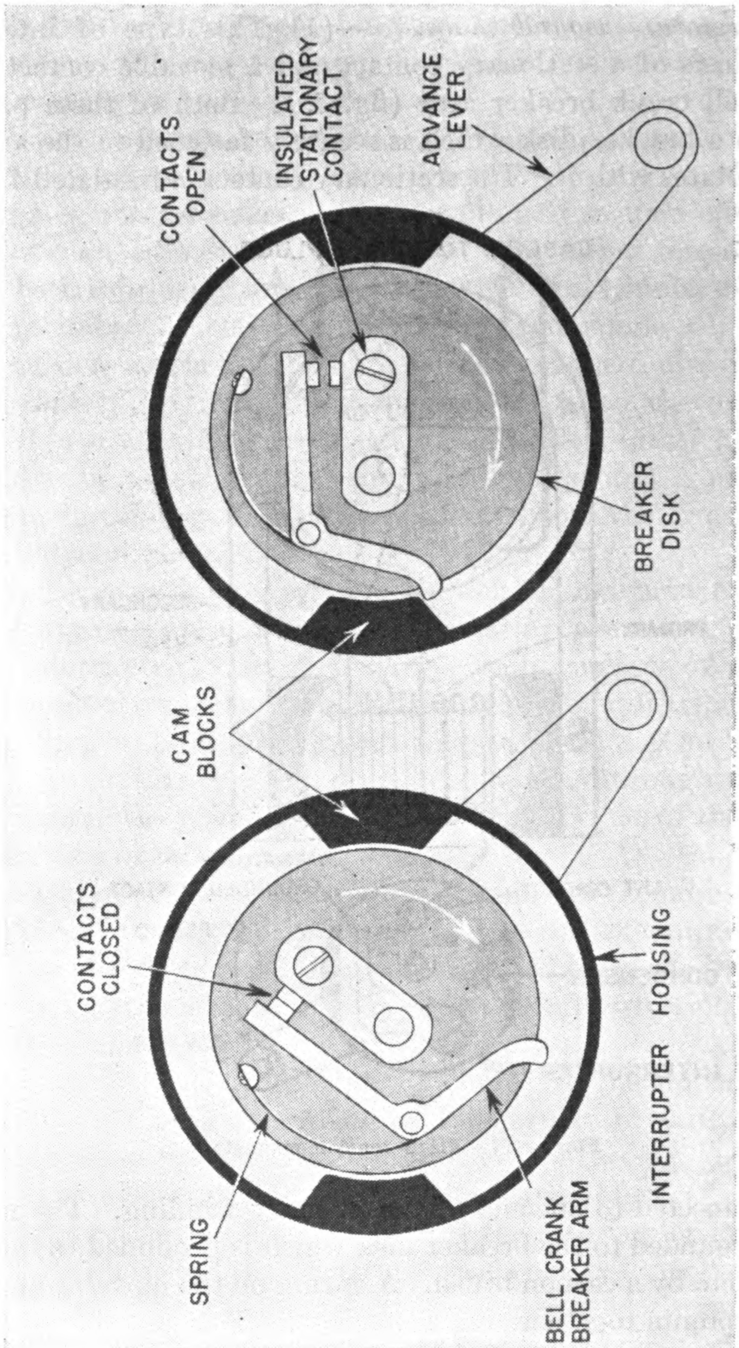



FIGURE 78.—Interrupter for armature wound magneto.

cam blocks are placed opposite each other on the interrupter housing (fig. 80) so that the contact breaker points are separated twice during one revolution. The housing is stationary and mounted opposite the driven end of the magneto shaft. As the breaker disk rotates with the armature, the outer arm of the bell crank is pushed by the two cam blocks to separate the breaker contacts twice each revolution. A lever is provided on the interrupter housing so that the cam blocks can be shifted to advance or retard the spark.

*b. For inductor magneto.*—For this type of magneto, the interrupter remains stationary with the winding and is operated by a two-lobe cam on the end of the magneto shaft. To minimize wear on the cam, the hinged breaker arm is sometimes operated by a roller at its center (fig. 79). The breaker arm and the stationary contact are mounted on a breaker plate which is attached to the interrupter housing. The breaker plate can be shifted in either direction with respect to the cam for timing the spark.

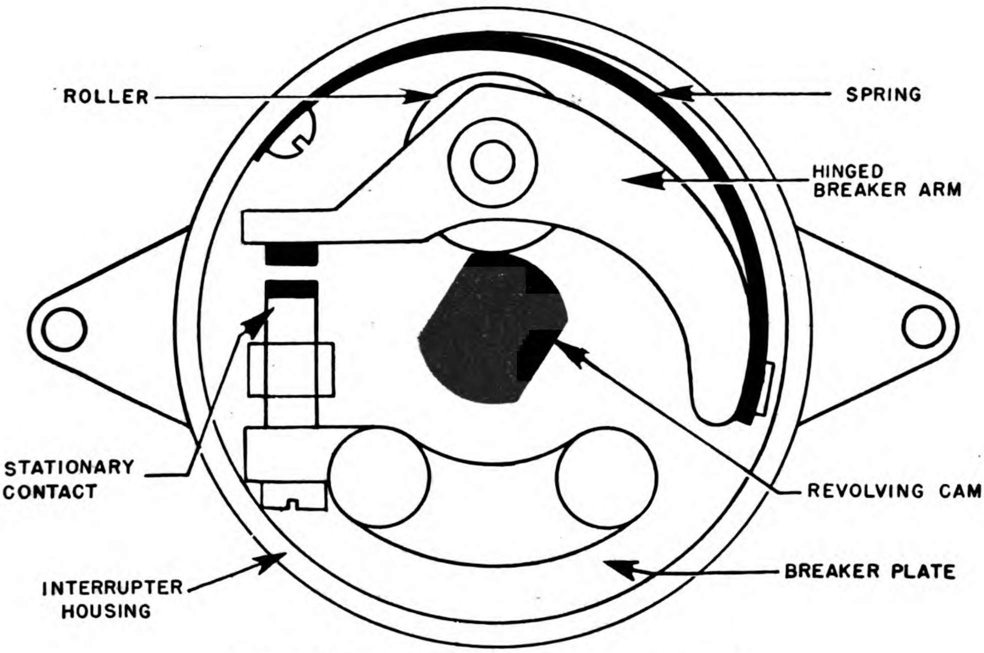



FIGURE 79.—Interrupter for inductor magneto.

*c. Operation.*—The circuit through the primary winding on the armature is completed when the breaker contacts are together, which starts the flow of current in the circuit. The cam, whether stationary or revolving, opens the circuit at the moment of maximum current in the primary winding. This breaking of the current provides the impulse necessary to induce the maximum voltage in the secondary

winding. At the same moment that the breaker contacts open, the distributor rotor is passing close to one of the spark plug terminals in the distributor head so that a path is opened to the spark plug for the high tension current. The distributor is driven directly from the armature of the magneto by gears so that the distributor rotor is at a point corresponding to the cylinder that is to be fired each time the breaker contacts open.

**48. Gearing.**—The ratio of the gears used to drive the distributor depends on the number of cylinders to be fired. The distributor should always be driven at half engine speed since half of the spark plugs must be fired for each revolution of the engine. However, the number of voltage peaks that the magneto supplies to accomplish ignition is limited by the number of poles (usually two) in the magneto.

*a.* For a 4-cylinder engine, two sparks are needed for each revolution of the crankshaft; therefore, the magneto shaft should run at engine speed. However, the distributor gear must rotate at half engine speed. Accordingly the ratio of the distributor gears in a magneto for a 4-cylinder engine is 2 to 1.

*b.* A 6-cylinder engine requires three sparks for each revolution but the ordinary magneto is only capable of producing two sparks for each revolution of its shaft. For this reason, it is necessary to run the armature shaft of a magneto on a 6-cylinder engine at one and a half times the engine speed. The distributor gears in the magneto must drive the distributor shaft one-third the speed of the armature shaft. The gears then have a 3 to 1 ratio.

*c.* Likewise, for an 8- or 12-cylinder engine a magneto that gives two sparks per revolution must be driven at two or three times crankshaft speed to produce the required number of sparks. Distributor gears of 4 to 1 or 6 to 1 ratio must be provided to reduce the distributor speed to one-half the engine speed.

**49. Inductor type magneto.**—The changing magnetic field for the inductor type magneto is obtained by means of various rotors which are of different designs for low and high tension magnetos. One type of rotor is made of soft iron poles, known as inductors, that receive their magnetism from the conventional horseshoe permanent magneto. In another type, the rotor itself is the permanent magnet, allowing a very simple construction.

*a. Low tension.*—Figure 80 shows the operating principle of one type of inductor magneto designed for low tension. In this magneto, the winding is built in the form of a doughnut-shaped stationary coil placed between inductors with the magneto shaft revolving through the center of the coil. The permanent magnet is one of

the horseshoe type with the rotor revolving between the poles. The rotor consists of two soft iron inductors on the rotating shaft, one extending in one direction and other in the opposite direction. Two positions of the inductors are shown in figure 80 with two views of each position shown to clarify the magnetic circuit through the inductors. In figure 80 ①, these inductors are in such a position that the lines of force from the north to the south pole go into the upper inductor (bottom view) and down through the shaft passing through the coil and then through the lower inductor to the south pole. Note that in figure 80 ① the lines of force go *down* through the coil. When the shaft makes one-half a revolution, the inductors are in the position shown in figure 80 ②. The lines of force still continue to go from the north to the south pole but in doing so they first go to the lower inductor and then *up* through the coil to the upper inductor. In this way, the continuous rotation of the shaft with its inductors causes a continuous changing magnetism to take place through the coil and produces a voltage in the winding. With this construction, the magnetism of the inductors reverses twice for each revolution.

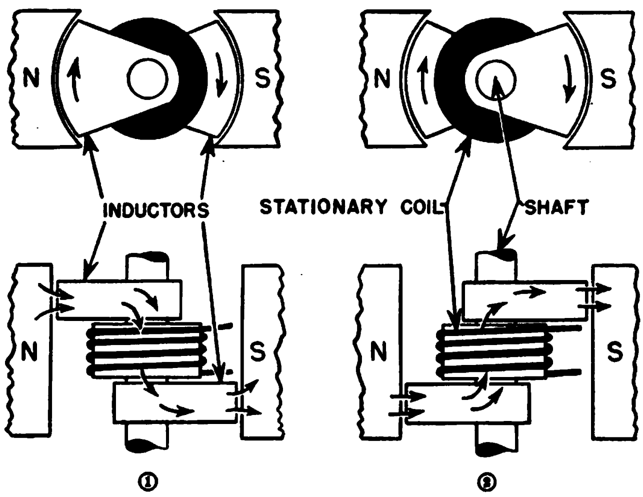



FIGURE 80.—Magnetic circuits of a low tension inductor magneto.

*b. High tension.*—(1) *Rotating inductors.*—(*a*) Another method of mounting inductors on a shaft is shown in figure 81. The polarity of the inductors does not change in this construction. The central portion of the shaft is made of bronze, which is nonmagnetic and does not carry the magnetism from one inductor to the other. The magnet is placed in such a way that the shaft goes through both the north and the south pole. In practice this is accomplished by having the magnet

in two pieces, each piece having a semicircular notch to take the shaft. Each inductor remains next to one pole and acts like the permanent magnet pole, but as these inductors are on the rotating shaft, the effect is that of rotating magnetic poles.

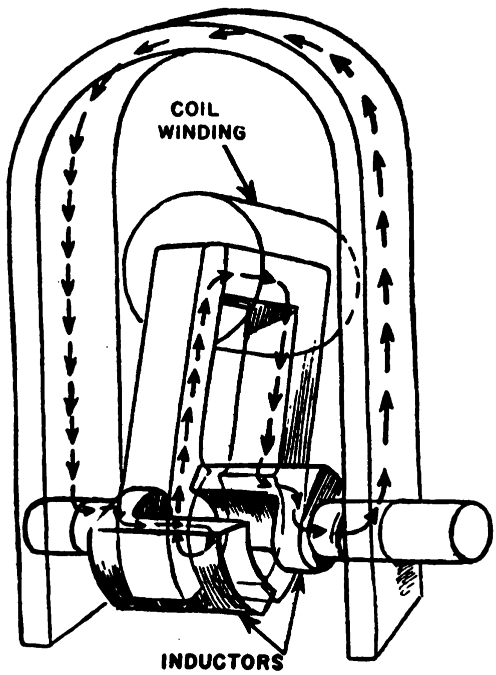



FIGURE 81.—Magnetic circuit of a high tension inductor magneto.

(*b*) As shown in figure 81, the rotating magnetic poles revolve between the ends of a U-shaped piece of soft iron on the upper portion of which is located the magneto coil winding. As the shaft revolves, the magnetism travels first one way and then the other way through this U-shaped piece of soft iron and in reversing produces voltage in the winding.

(2) *Rotating magnet.*—(*a*) Instead of the conventional horseshoe magnets, a rotating magnet is sometimes used to reverse the magnetic field through the core of the coil. Many modern magnetos use this principle because it is very adaptable to high tension ignition.

(*b*) Figure 82 shows the construction of this type of magneto. The coil assembly, consisting of a laminated steel core upon which is mounted the coil windings, is stationary. The rotating magnet is made up of bar magnets that are fastened between laminated iron poles. This magnetic rotor, which is mounted on a steel shaft, rotates between laminated iron pole shoes and produces an alternating magnetic field in them and through the core of the coil. Alnico, an exceptionally strong magnetic material that will lift 30 to 50 times its own

weight, is used for the bar magnets on the rotor, giving a very effective magnet with very little rotating weight. The rotating magnet type of magneto is compactly and simply constructed and has a minimum number of rotating parts.

**50. Impulse starter.**—*a.* Since the average engine cannot be cranked fast enough by hand to start it with the ordinary magneto,

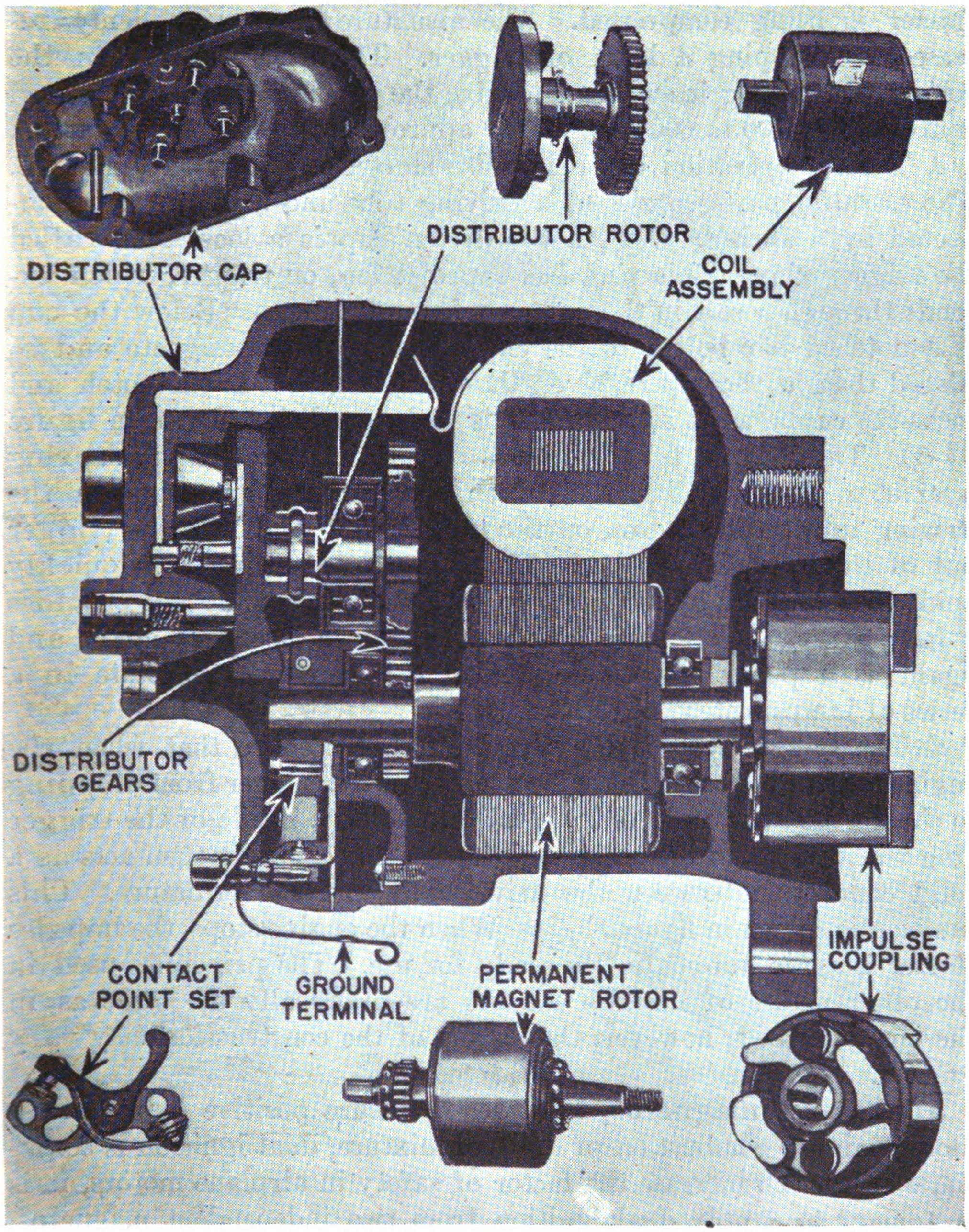



FIGURE 82.—Inductor magneto with rotating magnet.

an impulse starter is attached to the magneto to generate sufficient current for a hot spark regardless of engine speed. It consists of a mechanically operated spring device which throws the magneto armature, or rotor, at high speed for approximately half a revolution, thus producing a high voltage and a good spark.

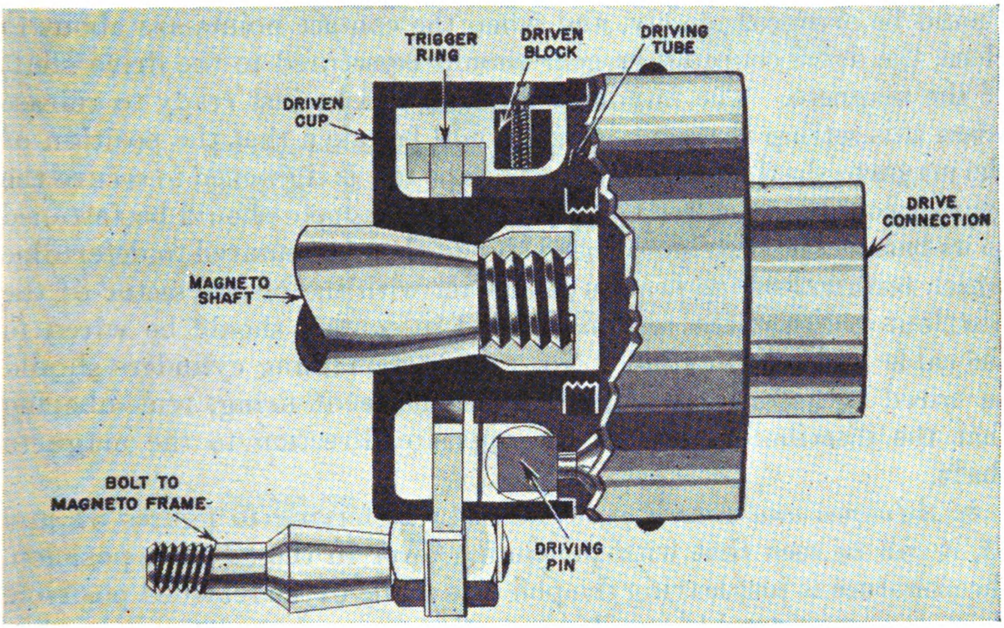
*b.* The impulse starter coupling must keep the magneto shaft from rotating for a short period during which the spring in the impulse starter is being compressed. The armature is then suddenly released by tripping a latch or trigger. The energy stored in the compressed spring is sufficient to give the armature a rotative speed equivalent to 500 to 600 r. p. m. for approximately half a revolution.

*c.* Typical operation of an impulse starter is shown in figure 83. The essential parts consist of a driving tube and a driven cup connected by a spring. Within the driven cup is a loose ring called the trigger ring. This ring has a projection, or trigger, which extends through a slot in the outer surface of the cup. Below the cup is a notched bar bolted to the end housing of the magneto and so placed that, as the cup revolves, the trigger catches in the notch and locks the cup against rotation. This is the condition shown in figure 83 ②. The driving tube continues to turn, compressing the spring against a block fixed to the driven cup until an extension on the driving tube strikes a cam on the trigger ring and lifts the trigger out of the notch in the bar. The compressed spring then quickly spins the armature of the magneto past the firing point and provides a hot spark. At cranking speeds, the trigger is caught again and again as it passes the notch causing the armature to rotate in a series of jumps instead of uniformly.

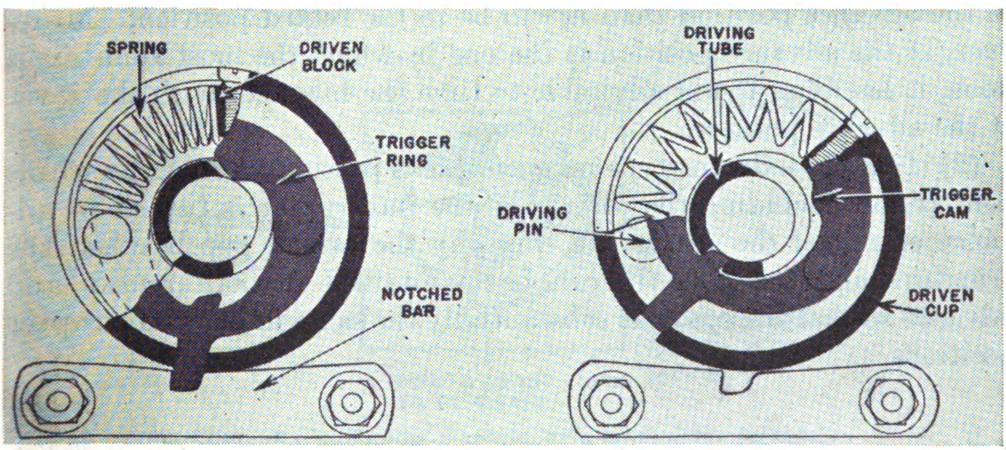
*d.* The trigger ring is heavily counterbalanced so that when the engine is running, centrifugal force prevents the trigger from dropping to the notched bar and holds a projection on the inside of the trigger ring within a notch in the driving tube. The coupling then acts as a solid connection between the drive shaft and the armature. This position is shown in figure 83 ③. When the engine stops, the impulse starter is again automatically ready for use. The principles used in the other makes of impulse starters are practically the same as in the one described; however, the details of the construction may vary greatly.

**51. Double magneto.**—In order to insure positive firing and a more complete combustion of the fuel mixture, dual ignition is sometimes used. To increase the factor of safety in airplane motors, it is customary to supply dual ignition from two independent magnetos. In other types of engines, however, the two sparks are provided from

one magneto which fires two spark plugs in series. Such a magneto has both ends of the secondary winding brought out to separate insulated terminals. A distributor is connected to each terminal to supply two sparks to each cylinder simultaneously. Enough voltage must be produced in the winding of the double magneto to jump two spark gaps in series. This system is generally provided with a switch to cut off the ignition entirely and also cut out one set of plugs when it is necessary to obtain a hot spark for starting the engine.




① Cross section.




② Trigger caught in notch (spring compressed). ③ Trigger released (spring extended).

FIGURE 83.—Impulse starter.

**52. Magneto timing.**—*a. Methods.*—The same general methods are used in timing practically all types of high tension magnetos used on motor vehicles. The engine should be cranked until one of the pistons, preferably that of cylinder No. 1, is at top dead center at the end of the compression stroke. The impulse starter should be locked or wedged out so that it will not catch while timing the magneto. It is best to follow the manufacturer's instructions. With the magneto drive coupling, or gear, disconnected, the driving shaft of the magneto should be rotated against the direction it is driven. The breaker should be observed closely, and when the contact points are about to close, the drive coupling or gear should be secured to the drive shaft of the magneto. The impulse starter should be just ready to release when this setting is made. Care should be taken that the position of the magneto shaft is not altered when the nut is tightened to secure the gear or coupling. After this is done, the magneto should be fastened to its base. The distributor head should then be removed to determine which terminal of the head is in contact with the bronze sector of the distributor disk. The terminal found in contact should be wired to the cable leading to cylinder No. 1. The remaining cylinders should be wired in accordance with their sequence of firing, remembering that the distributor runs in the opposite direction to the magneto shaft.

*b. Advance and retard position.*—(1) Referring to figures 84 and 85, it can be seen that with the timing lever in the advance position, the armature is just leaving the pole tips while in the retarded position, there is a considerable gap between the armature and the pole tips. This means that, other things being equal, the spark will be stronger in the advance position than it will be in the retard position. Moreover, as the advance position is the one in which the most running is done, it has been found advisable to time the magneto with the lever at the advance position.

(2) In some inductor type magnetos, it is possible to rock the whole field frame, including the coil, when the interrupter is turned to advance or retard the spark. In this way the proper gap between the armature and the pole tip can be maintained in both retard and advance so that the spark is substantially the same in both interrupter positions.

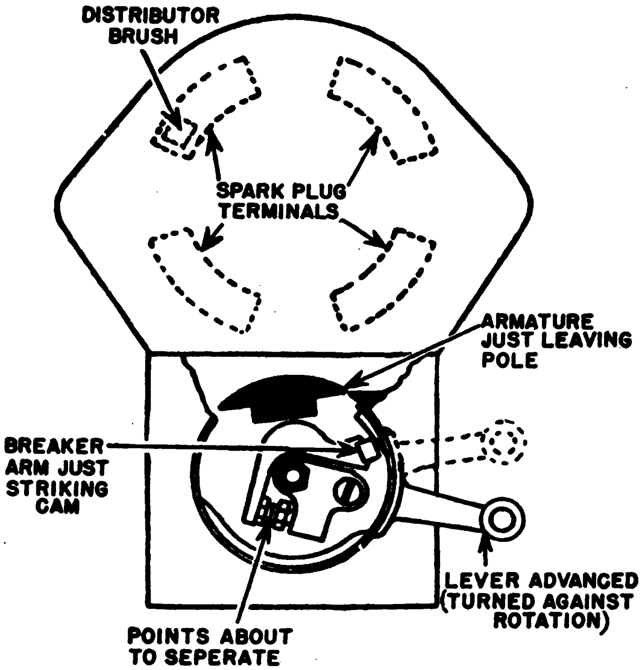



FIGURE 84.—Timing magneto with spark lever advanced.

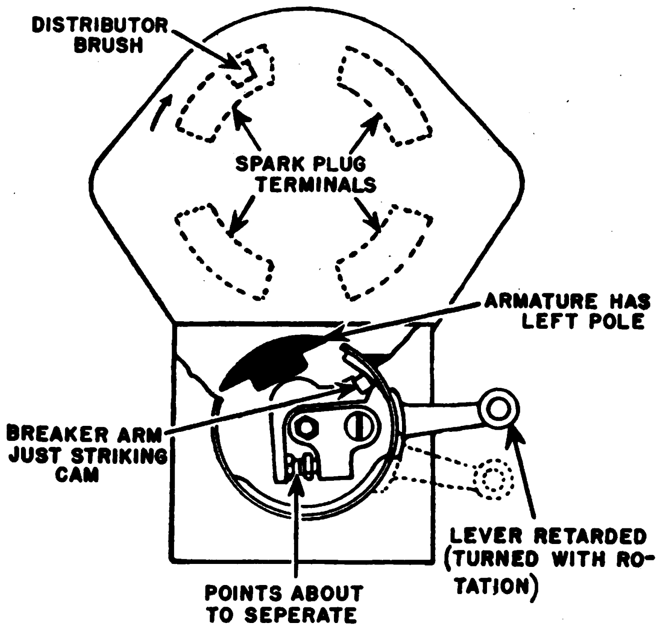



FIGURE 85.—Timing magneto with spark lever retarded.

## SECTION VI

# STARTING AND GENERATING SYSTEMS



**53. General.**—*a.* Mechanical and air starters have been discarded in favor of the electric starter which is now furnished as standard equipment on all makes of passenger cars, on a large percentage of trucks, and on some tractor, airplane, and marine engines. The electric starter is a low voltage direct current motor capable of developing high torque. The current for operating this motor is supplied by a storage battery, which also furnishes the current for the lighting system and, in most cases, for the ignition.

*b.* The typical electric starting and generating system consists of the following essential units:

(1) A direct current starting motor that will operate on current from the storage battery for cranking the engine.

(2) A storage battery for supplying current when the generator is not running or when its output is insufficient to meet the demands of the electrical system.

(3) A direct current generator driven by the engine to keep the battery charged and to operate the electrical units when the engine is running.

*c.* The generator and starting motor can be combined into one machine known as a motor-generator or starter-generator. However, this use of one machine for the starting and generating system is obsolete. More efficient operation is obtained in modern vehicles by

having generator and starting motor as two independent machines. The generator is driven continuously by the engine, while the starting motor is normally disconnected from the engine and operates through its driving mechanism only when the starting switch is closed and the engine is cranked. The general arrangement of a starting motor and a generator is shown in figure 86.

*d.* The single-wire method of wiring is used in preference to the two-wire method by practically all motor vehicle manufacturers since the use of the frame in place of one wire greatly simplifies both the wiring of the vehicle and in many cases the construction of the starting and generating apparatus.

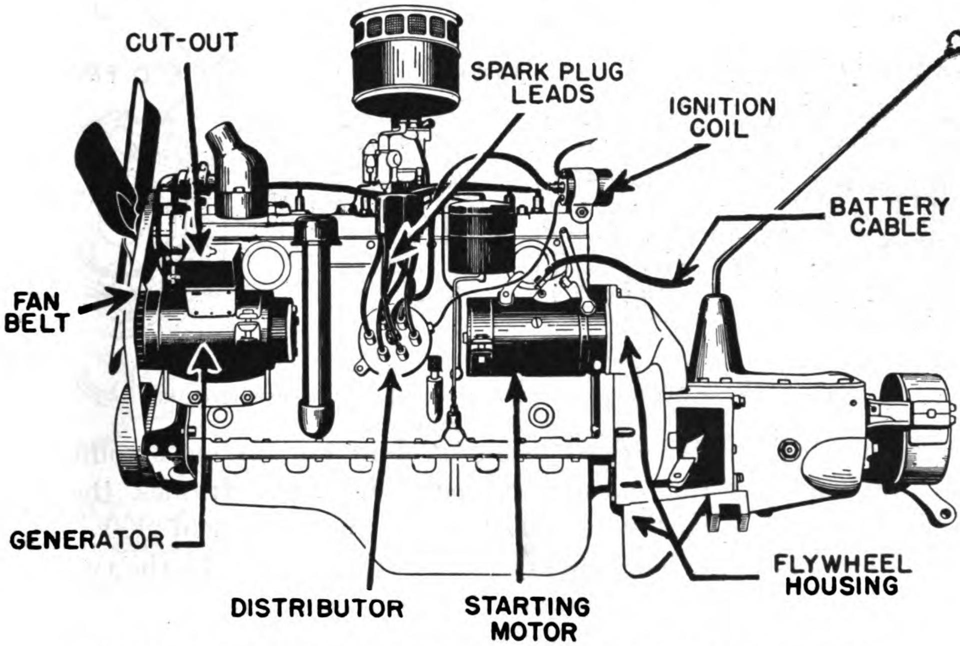



FIGURE 86.—Typical arrangement of a starting motor and a generator.

**54. Generator.**—*a.* The generator is a machine in which the principle of electromagnetic induction is used to convert mechanical energy into electrical energy. A generator and a motor are fundamentally the same, although their operation is opposite. By reversing its operation, one unit may be made to serve both purposes, as is done in the one-unit system.

*b.* The generator consists essentially of an armature; a field frame; field coils; and a commutator with brushes, or collector rings with brushes, to establish electrical contact with the rotating element. The magnetic field of the generator is usually produced by electromagnets or poles magnetized by current flowing through the field coils.

Soft iron pole pieces are contained in the field frame that forms the magnetic circuit between the poles. Two- and four-pole frames are the most common although machines may be designed to have any even number of poles.

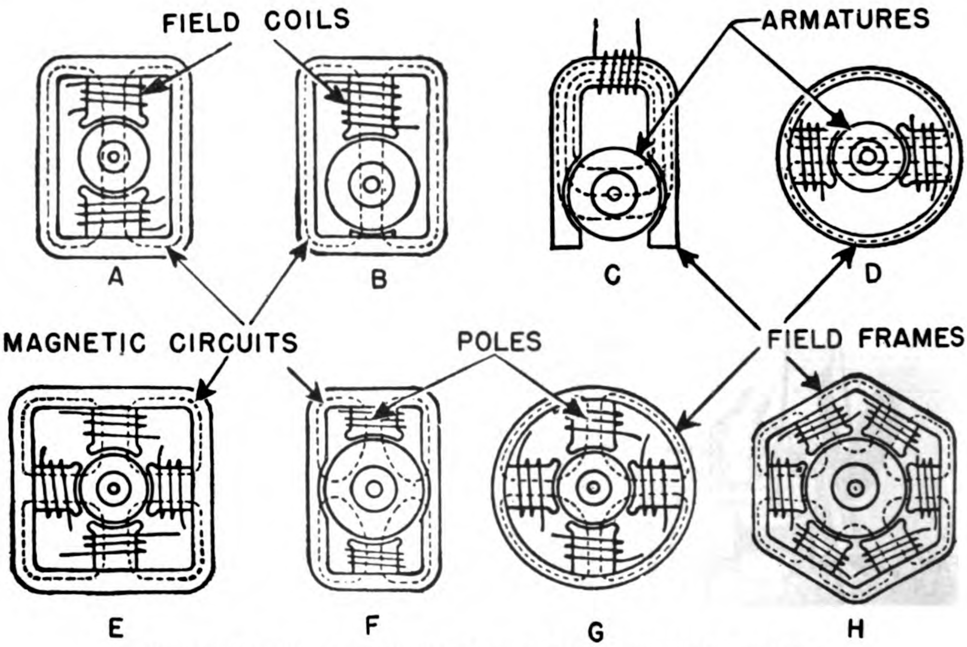



FIGURE 87.—Types of field frames and their magnetic circuits.

*c.* Figure 87 shows several types of field frames most commonly used and the magnetic circuits in each. On some frames, the field coil is wound on each pole to produce the magnetic field *A*, while in others there is but one large field coil to two poles, *B*. In the two-pole type of frame the magnetic circuit flows directly across the armature, *A*, *B*, *C*, and *D*, while in the four- and six-pole types each magnetic circuit only flows through a portion of the armature core, *E*, *F*, *G*, and *H*. For this reason the armature must be constructed in accordance with the number of field poles, since current is generated by the coil winding on the armature cutting each magnetic circuit.

*d.* The current is collected from the armature coils by the brushes (usually made of carbon) which make rubbing contact with a commutator or collector rings. The commutator consists of a series of insulated copper segments mounted on one end of the armature, each segment connecting to one or more armature coils. The commutator converts the alternating current generated in the armature coils into direct current for charging the battery. The armature coils of an alternating current generator are connected to collector rings which

collect the current in the same form as it is generated in the armature windings.

**55. Simple alternating current generator.**—*a.* If a single loop of wire is revolved in the magnetic field between a north pole and a south pole, there will be an electrical pressure induced in the two sides of the loop; and the voltage and current induced will be in definite relation to the direction of magnetism and the direction of rotation. If each end of the loop is connected to a metal collector ring upon which a brush rests, as *C* and *D* (fig. 88), this induced electrical pressure will cause a current to flow through any external circuit which may be connected across the two brushes.

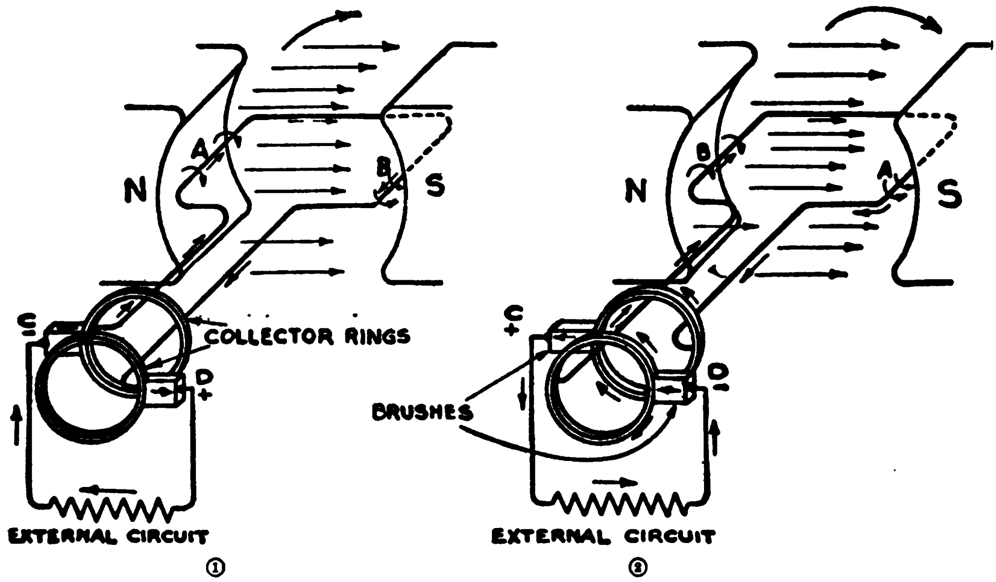



FIGURE 88.—Simple alternating current generator.

*b.* If the loop is rotated through a complete revolution, sides *A* and *B* will cut magnetic lines of force first in one direction (fig. 88 ①) then in the other (fig. 88 ②), inducing an alternating voltage across the brushes and causing an alternating current to flow through the external circuit. A study of figure 88 shows that the current will make one complete reversal or cycle in one revolution of the loop. The value of the current during one complete revolution of the loop may be represented graphically by the curve (fig. 89) known as the sine curve. The highest and lowest points of the curve represent the current at its maximum value which is reached when the loop is in line with the field poles.

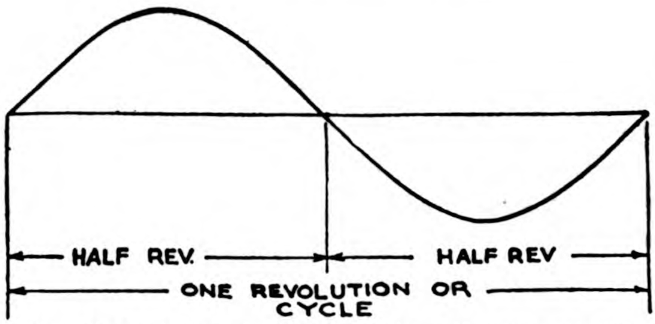



FIGURE 89.—Current wave from simple alternating current generator.

**56. Simple direct current generator.**—*a*. The alternating current produced in the loop may be converted into direct current in the external circuit by replacing the two collector rings with a simple two-segment commutator (fig. 90). The two segments of the commutator are connected to the two ends of the loop but insulated from each other. The only connection between the commutator segments, besides the one through the armature loop, is through the brushes and the external circuit. The brushes remain stationary and make rubbing contact first with one segment and then with the other, as the commutator and loop rotate as a unit. With this arrangement, the segments change connection with the brushes as the induced voltage reverses in the loop. As a result, the current is always made to flow through the external circuit in the same direction. The current thus obtained is a direct current, graphically represented in figure 91. Comparing figures 91 and 89, it can be seen how use of a commutator produces direct current by reversing one of the impulses of current generated in the generator.

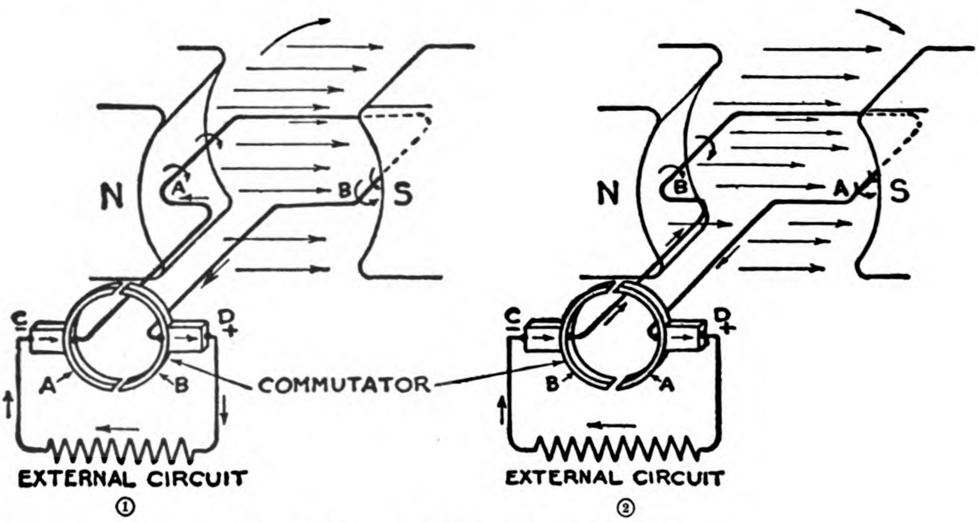



FIGURE 90.—Simple direct current generator.

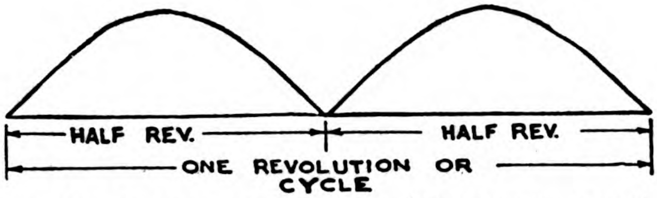



FIGURE 91.—Current wave from simple direct current generator.

*b.* In practice, the armature core, which is in the form of a laminated iron cylinder, is wound with a great many coils equally spaced around its circumference, each coil being connected to a pair of segments in the commutator. These coils are connected so that the current impulse of one coil overlaps the current impulse of the next much the same as the power impulses overlap in an eight- or twelve-cylinder engine. The result is practically a continuous steady flow of current.

**57. Simple direct current motor.**—*a.* If the brushes of the simple generator (fig. 90) are connected to a battery and current permitted to flow through the loop of wire (fig. 92), the loop of wire

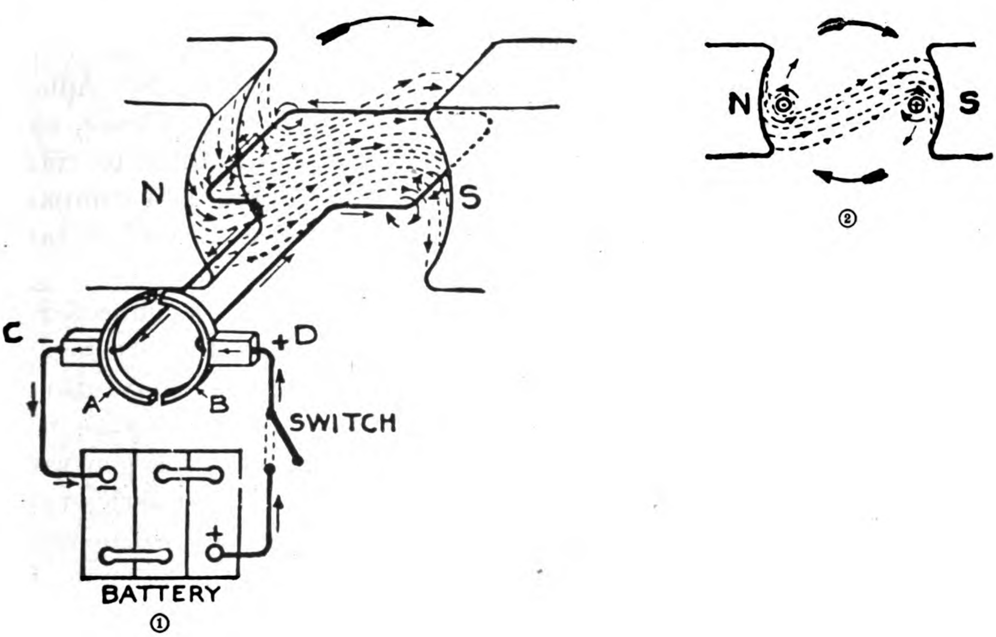



FIGURE 92.—Simple direct current motor.

will rotate in the direction indicated by the arrow. Briefly, this rotation is due to the repulsion between the field magnetism and the magnetic whirl set up around the loop of wire by the current.

*b.* The repulsion is caused by all the magnetic lines of force tending to flow around the conductor in the same direction. This dis-

torts and crowds the magnetic lines on one side of the conductor more than on the other, which results in a repulsion of the conductor (fig. 93 ①). If the magnetic field is reversed, with the direction of current unchanged, the magnetic lines of force will crowd to the other side of the conductor and it will be repelled in the opposite direction (fig. 93 ②). The same action would result if the current, instead of the magnetism, were reversed. Thus in figure 92, owing to the current flowing in the two sides, *A* and *B*, of the loop in reverse directions and the consequent field distortion (fig. 92 ②), *A* will be repulsed upward and *B* downward, and the loop will rotate in a clockwise direction.

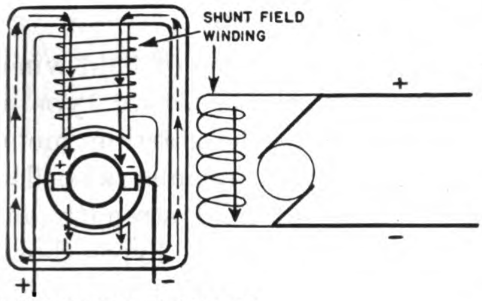

FIGURE 93.—Wire repulsion in a magnetic field (current going in).

*c.* In practice, the motor armature has many armature coils equally spaced around the entire circumference of the armature core, each of which carries current and, consequently, exerts a force to rotate the armature as it passes the pole pieces. The result is a comparatively high turning power or torque which, if applied through suitable gear reductions, is sufficient to crank the engine.

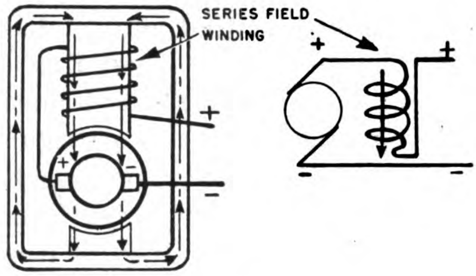
**58. Field windings.**—*a.* The field winding may be connected in parallel with the armature winding, that is, across the brushes, in which case it is known as a shunt field winding. It may also be connected in series with the armature winding, in which case it is known as a series field winding. The magnetic field of a generator or motor is produced by a field winding of the shunt or series type, or a combination of the two. Various methods may be used in winding the field poles of a generator or motor to suit the purpose for which it is to be used. Figure 94 shows the different ways in which the shunt and series field may be connected on the same type of frame, the markings and arrows refer in each case to the direction of current for a generator. The small diagram to the right of each main sketch is the conventional way of indicating briefly the particular type of field winding.

*b.* By applying the right hand to determine the magnetic polarity of an electromagnet, it will be seen that in figure 94 ③ and ④, the

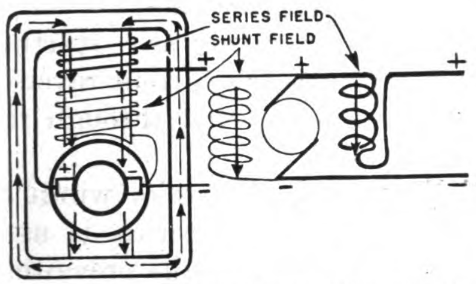
shunt and series windings produce magnetism in the same direction. They are, therefore, said to be cumulatively wound. In figure 94 ⑤ and ⑥, the magnetism produced by a current flowing in the series field winding is opposite to that produced by the shunt winding, and the dynamos are said to be differentially wound.



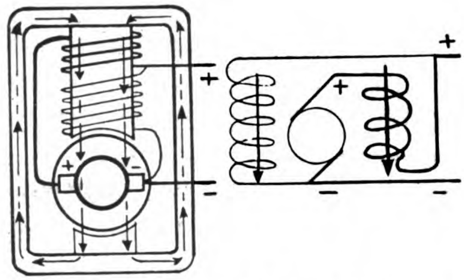

① Shunt wound dynamo.



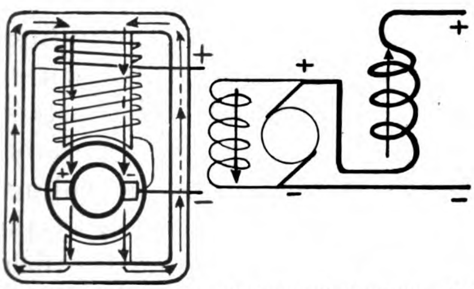

② Series wound dynamo.



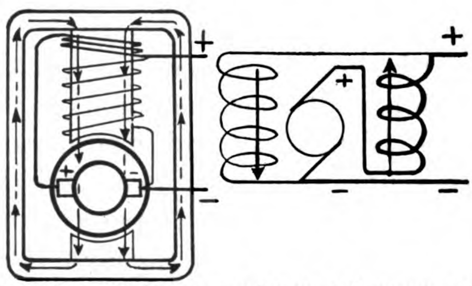

③ Cumulative compound wound dynamo with short shunt.



④ Cumulative compound wound dynamo with long shunt.



⑤ Differential compound wound dynamo with short shunt.



⑥ Differential compound wound dynamo with long shunt.

FIGURE 94.—Types of field windings.

*c.* The shunt field may be connected either inside or outside the series field winding. When it is connected inside (fig. 94 ③ and ⑤), it is known as a short shunt connection, and when it is connected outside (fig. 94 ④ and ⑥), it is known as a long shunt connection. The principle of each is similar, the difference being that in a short

shunt connection the shunt field current does not pass through the series winding. In practice, generators represented by figure 94 ③ and ④ are not used on the automobile because the generator must necessarily run at variable speeds and any increase in armature speed and voltage would increase the field strength and consequently the armature output would increase to a point where it would overload the generator as well as overcharge the battery.

*d.* The shunt type of winding (fig. 94 ①) is the type of field winding generally used for automotive generators. The series type of winding (fig. 94 ②) is particularly adapted to the starting motor because all the current passing through the armature must also flow through the field winding, thus producing full field strength and giving the motor the greatest possible cranking power. Types shown in figure 94 ⑤ and ⑥ are particularly adapted for motor generators used on the one-unit system. When operating as a generator, the windings function differentially, the series field bucking the shunt field to produce a regulating effect. When operating as a starting motor, the windings function cumulatively since the current reverses through the armature and the series winding but not through the shunt winding.

*e.* When a generator is differentially wound, the series winding, which is commonly known as a reverse or bucking series, is used only for regulating purposes, the shunt winding being the prevailing winding and controlling the direction of magnetism. The shunt field winding may be readily distinguished from the series, since it consists of a large number of turns of small wire, while the series winding consists of a comparatively few turns of large wire. Windings must be well insulated. In some cases, they are impregnated with a special insulating compound to make them water and oil resistant.

**59. Shunt wound generator.**—Most motor vehicle generators are shunt wound with an outside means of regulating the voltage output. About 8 to 12 percent of the total current generated by the armature is shunted through the field coils for producing the field magnetism. Figure 95 represents a shunt wound generator with only one armature coil. The armature is actually wound full of similar coils distributed at equal intervals around it, the end of each coil being connected to a segment of the commutator in the same manner as the one shown.

*a. Principle of operation.*—In figure 95, let it be assumed that the armature rotates in a clockwise direction and that the magnetism flows from the north pole piece *N* to the south pole piece *S* as indicated by the arrows. When the armature is rotated, the armature

coils will cut the weak magnetic field (residual magnetism) retained by the poles and set up a slight voltage across the brushes, usually 1 to 1½ volts, making in this particular case the upper brush positive (+) and the lower brush negative (−). This voltage is sufficient to cause a small current to flow from the positive brush through the field winding around the pole pieces to the negative brush. If the magnetic effect of this field current is of the same polarity as the residual magnetism, the pole strength will be increased. This, in turn, will increase the magnetic field through the armature. Since

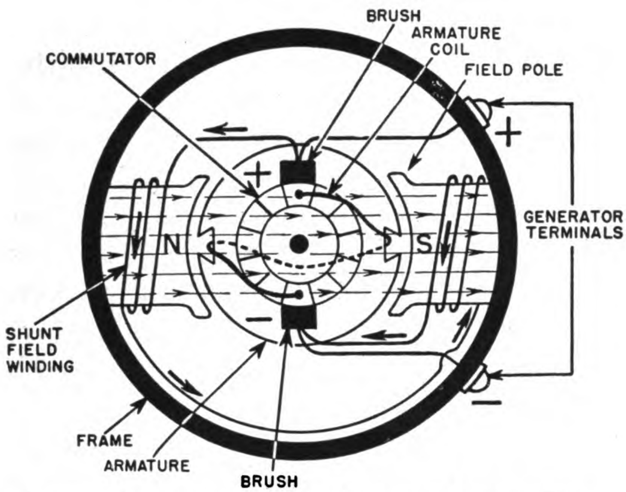



FIGURE 95.—Diagram of a shunt wound generator.

the armature coils will then be permitted to cut more magnetic lines of force per revolution, the voltage across the brushes will be increased. An increase in brush voltage increases the field strength, which in turn, increases the armature output. Thus, the armature voltage helps the field and the field helps the armature voltage until the generator reaches its normal operating voltage at the particular speed it is running. This process is called "building up" the generator voltage.

*b. Residual magnetism.*—(1) In the above description of generator operation, the importance of the magnetism retained by the poles should be noted as it serves as a foundation for building up the generator voltage.

(2) Residual magnetism is the name given to the magnetism remaining in the pole pieces and field frame after the field magnetizing current has died out. The direction of the residual magnetism may be tested by holding a pocket compass near the poles when no current is passing through the field windings or the armature. The

north end of the compass needle will point to the south field pole and the south end to the north field pole.

(3) In case the field frame should lack proper residual magnetism, which may be due to its being a new machine, connecting the field winding with alternating current supply, excessive temperature, or vibration, the generator may be given residual magnetism by simply sending direct current through the shunt field winding in the proper direction from either a storage battery or dry cells. This residual magnetism may be reversed by merely reversing the direction of the magnetizing field current. It may also be reversed by the magnetizing effect of the armature coils when a heavy direct current from a battery is sent through the generator armature with the field winding disconnected or open circuited.

(4) Several conditions are necessary for the generator to build up a voltage. Two of the most important requirements are that the field frame have residual magnetism as a foundation on which to build, and that the current in each field coil be in such direction around the pole that it will produce magnetism to assist and not oppose the residual magnetism. If the field current opposes it, the voltage built up will not be higher than that produced by the residual magnetism.

*c. Construction.*—(1) The armature core is made of sheets of iron insulated from each other so that the magnetic field will not induce eddy currents in the core. These eddy currents will flow around the core if it is made of one solid piece of iron and heat the armature.

(2) The armature core is wound with coils of copper wire and mounted on a shaft with a commutator on one end (fig. 96). Field coils are made of many coils of fine wire arranged for shunt connection. The field frame, usually two or four poles with brushes, brush holders, and end housings with bearings, completes the essential parts of the machine.

*d. Generator drives.*—(1) The method of mounting and driving the generator depends to a large extent upon the construction and design of the engine. It is usually mounted on the side of the engine and driven at one to one and a half times the crankshaft speed by belt, silent chain, or gears.

(2) The present trend is to have the radiator cooling fan, water pump, and generator driven by a V-belt from the pulley on the forward end of the crankshaft (fig. 86). Pivoting the generator on the generator mounting studs permits adjustment of the belt tension. A rotary fan is usually contained on the generator pulley to draw cooling air through the generator.

*e. Lubrication.*—Oil cups are usually provided on both ends of the generator to supply oil to the bearings. Several drops of light engine oil should be added every 1,000 miles to maintain proper lubrication.

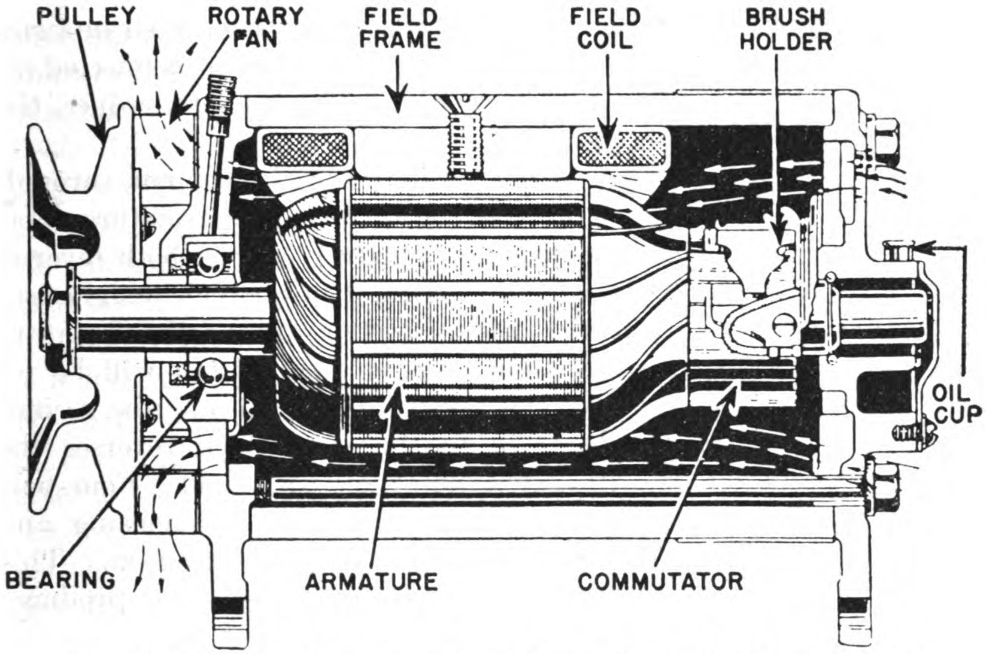



FIGURE 96.—Construction of generator. (Arrows show path of circulated air.)

**60. Starting motor.**—*a. General.*—(1) The series wound motor is particularly adapted to cranking motor vehicle engines because it has a very heavy starting torque, a quick drop in current requirement as the motor attains speed, and a liberal overload capacity. It is essentially a variable speed motor since its speed increases as the load decreases. These are characteristics which make it valuable for use both as a starting motor for the gasoline engine and as a driving motor on the electrically driven vehicle, although in the latter it is seldom a simple series wound type. As its speed is inversely proportional to the load, it tends to race when the load is light. In other words, it will "run away" if the load is suddenly removed, as when declutching it from the automobile engine after starting the latter, unless the current is instantly shut off or very much reduced.

(2) The average starting motor is designed to deliver ½ to 1 hp., the average current consumption during the cranking period being 125 to 175 amperes in a 6-volt system. At the moment the starting switch is closed, however, it may draw as much as 500 to 600 amperes, the current decreasing in value as the engine is accelerated to

the full cranking speed. Thus all current carrying members, such as starting motor switch, cables, brushes, armature coils, etc., must be built to handle the heavy current without undue resistance and heating. The battery must also be capable of high discharge rates.

*b. To connect field coils.*—There are various methods of connecting the field coils of the starting motor before they are connected in series with the armature. The separate field coils may be connected in series with each other and also in parallel groups to reduce the resistance of the starting motor circuit.

*c. To reverse armature rotation.*—Reversing the current through the starting motor does not reverse the direction of armature rotation since the field magnetism and the armature current both reverse. However, should either the armature current or the field magnetism be reversed (but not both) the field distortion around the armature coils will be in the opposite direction and the rotation will be reversed. In practice, reversing the armature rotation may be accomplished by reversing the leads to the brushes which reverses the current through the armature but not the series field. Four-pole starting motors can be reversed by turning the end housing and brush rigging a quarter turn from their original position. This reverses the brush positions with respect to the field and produces the same effect as reversing the brush leads.

*d. Construction.*—The general construction of the starting motor is similar in many respects to that of the generator although the electrical connections differ slightly. The principal parts consist of the field frame and windings, armature, brushes and brush rigging, end housings and bearings, and the drive mechanism.

*e. Lubrication.*—Graphited or oil impregnated bearings are used on the drive end of the starting motor. These retain sufficient lubricant within the bearings to supply proper lubrication and require no attention. An oil cup is provided to supply oil to the bearing on the other end of the motor to which a few drops of light engine oil should be added every 1,000 miles.

**61. Starting motor drives.**—The starting motor may drive the engine through a silent chain or by a pinion attached to the motor armature shaft which is brought into mesh with teeth cut on the rim of the flywheel. The drive must be equipped with an overrunning clutch or some other means of quick disengagement. Owing to limitations of size and capacity of the battery, a high speed starting motor with a high gear reduction is used to obtain the necessary power. The great speed reduction required is effected in the majority of cases by utilizing the flywheel as a driven gear. In some instances,

the gear is bolted or shrunk on the flywheel, while in others the gear teeth are cut directly in the rim of the flywheel itself. The starting motor is mounted on the flywheel housing (fig. 86).

*a. Gear reduction.*—The gear reduction obtained through the flywheel gear with single reduction is usually about 11:1 or 12:1 (sometimes it is as high as 16:1); that is, the speed of the motor armature is 11 or 12 times that of the flywheel. The pinion gear on the armature shaft meshes directly with the gear teeth on the flywheel. In some cases, however, a double reduction is used in which the gear ratio may be as high as 25:1 or even 40:1. With double reduction, the gear on the armature shaft does not mesh directly with the teeth on the flywheel but with an intermediate gear which drives the flywheel driving pinion. The double reduction drive permits the use of a very small starting motor running at high speed, but it has the disadvantage of requiring a more complicated mechanism than the single reduction drive.

*b. Pedal shift.*—(1) With this type of starting mechanism, the starter pinion is meshed when the driver presses the starter pedal. Such a system is shown in figure 97. This system includes an overrunning clutch type of drive so that the pinion is automatically disengaged from the flywheel at the instant the engine begins to fire.

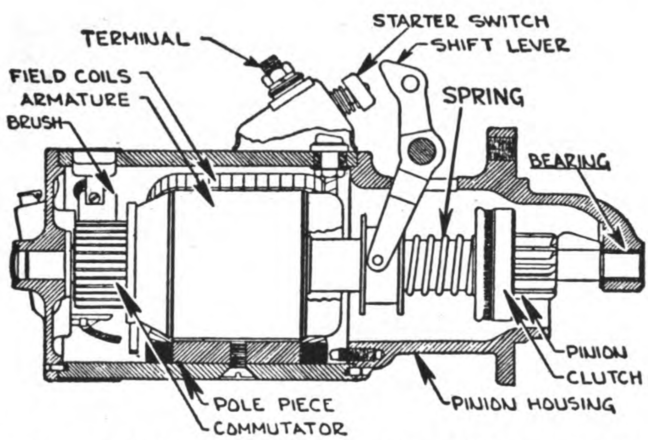



FIGURE 97.—Pedal shift starting motor drive with overrunning clutch.

(2) When the shift lever is moved by the action of the driver in stepping on the starter pedal, the pinion gear is shifted into mesh with the flywheel gear. After the gears are in mesh, continued movement of the pedal operates the starter switch and causes the motor to crank the engine. In case the pinion does not mesh perfectly with the flywheel, further motion of the shift lever compresses a spring so that the pinion will snap into mesh the instant the starting motor

armature begins to rotate. After the engine has started, releasing the starter pedal will pull the pinion out of the mesh.

c. *Overrunning clutch.*—Power can be transmitted through the overrunning clutch in only one direction, which prevents the engine from driving the starting motor. The outer race of the clutch (fig. 98) is driven by the starting motor shaft, the inner portion or clutch rotor being connected to the pinion which meshes with the teeth on the engine flywheel. Sometimes the outer race and rotor are connected in

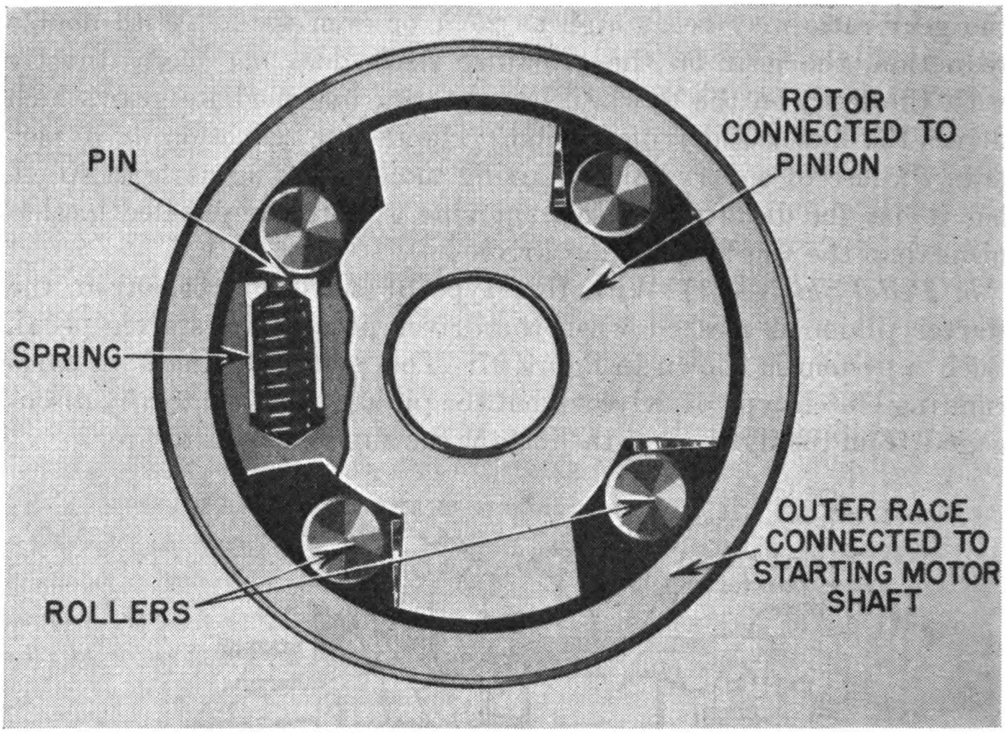



FIGURE 98.—Construction of a typical overrunning clutch.

the opposite manner. Steel rollers are located in wedge-shaped spaces between the rotor and the outer race. Springs and pins normally hold the rollers in position within the wedge spaces. When the starting motor shaft turns, the rollers are jammed between the wedge-shaped surfaces causing both the inner and the outer members to rotate as a unit and the motor to crank the engine. As soon as the engine tends to transmit power through the pinion in a reverse direction, the inner portion of the assembly (fig. 98) is driven by the flywheel and tends to work the rollers back against the pins to where the space is greater, thereby causing a slipping or overrunning action. As a result, the clutch cannot be driven in this direction. This prevents excessive speeds of the starting motor.

**62. Solenoid shift.**—Shifting the pinion gear into mesh with the flywheel gear is made automatic on a good proportion of modern vehicles by the use of a solenoid. A remote control switch of one type or another is necessary to operate the solenoid. The ignition switch is connected into the control circuit so that the starting motor will not operate until the ignition is on. The solenoid shift unit is rigidly mounted on the starting motor field frame. Inside the solenoid coil is a heavy plunger connected to the shift lever (fig. 99). The two larger terminal posts on the shift unit are connected in series with the starting motor. The smaller terminal which leads to the solenoid is connected into the remote control circuit.

*a. Operation.*—When the remote control circuit is closed to supply current to the solenoid coil, the solenoid exerts a pull on the shift plunger which shifts the pinion into mesh with the flywheel teeth. After the pinion shift lever has moved the distance required for meshing the pinion gear, the pointed end of the shift plunger presses against the end of a contact plunger and pushes a contact disk on the contact plunger across the switch contacts to operate the starting motor. An overrunning clutch is required with this system to prevent damage to the starter at the time the engine fires.

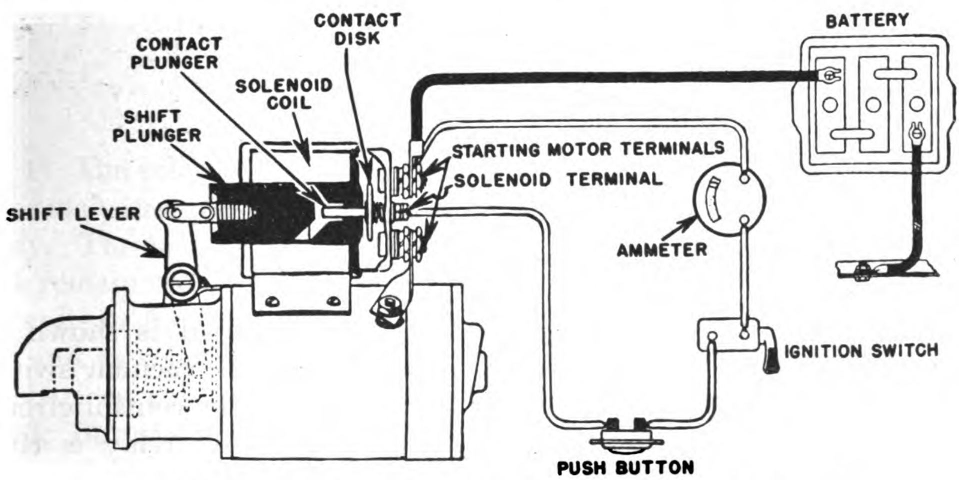



FIGURE 99.—Push button control of solenoid shift starting motor drive.

*b. Push button control.*—(1) One method of controlling the solenoid shift is by means of a push button on the instrument panel. Such a control is shown in figure 99. Pushing the button closes the control circuit so that current can be supplied to the solenoid coil.

(2) A relay is frequently used in the control circuit to supply current to the solenoid coil. Only a low current control circuit to the instrument panel push button is then necessary. The relay will close the circuit through the solenoid coil which carriers a larger current.

*c. Vacuum control.*—(1) A vacuum switch, operated by movement of the accelerator in combination with a control relay, is another method of controlling the solenoid. This combination, when properly adjusted, eliminates the possibility of the starting motor operating while the engine is running.

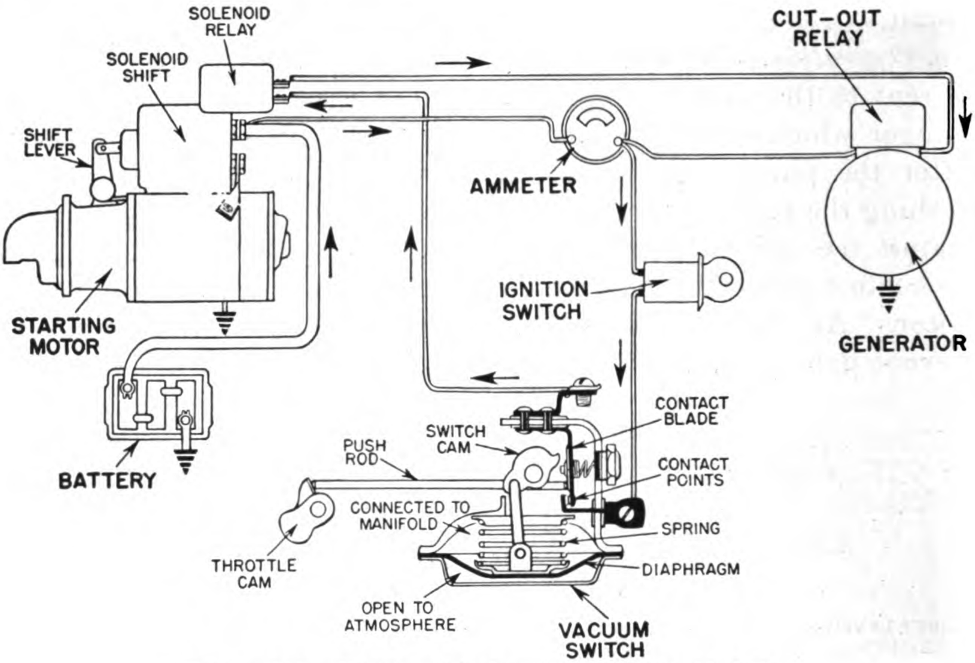



FIGURE 100.—Vacuum switch control of solenoid shift.

(2) Vacuum switch control of the starter solenoid is shown in figure 100. When the ignition switch is on and the vacuum switch contact points are closed, current will flow through the control circuit as indicated by arrows in figure 100. The solenoid relay is then energized and its contacts close to supply current to the solenoid shift unit which operates the starting motor. The control circuit is completed through generator brushes or field to the ground connection on the generator.

(3) Depressing the accelerator pedal operates a linkage which turns the throttle cam (fig. 100) counterclockwise and moves the push rod away from the contact blade. When the engine is not operating, the blade will move with the push rod to close the vacuum switch con-

tacts. The vacuum produced in the manifold when the engine starts causes the diaphragm to compress the spring and rotate the switch cam. The lug on the switch cam opens the contact points and latches on an insulated pin on the contact blade, holding the points open. When the engine stops or stalls, there is no vacuum in the intake manifold and the spring tends to push the diaphragm back to its original position, but it is held by the latched switch cam. When the foot is taken off the accelerator pedal, the push rod pushes against the contact blade sufficiently to unlatch the cam and allows the vacuum diaphragm to return to its original position. The contact points are held open by the push rod, but when the accelerator is depressed to start the engine, the push rod moves away from the contact blade and the points close to operate the starter solenoid.

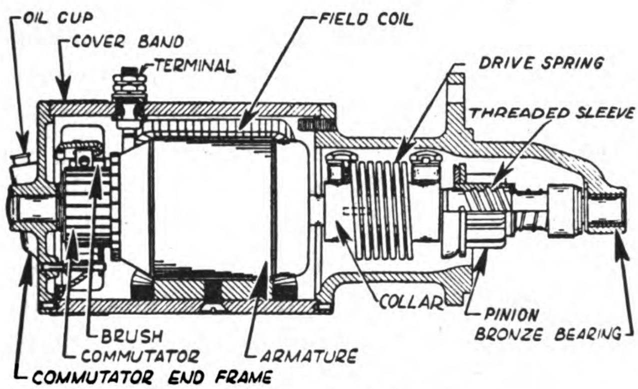



FIGURE 101.—Bendix drive.

(4) The solenoid relay is mounted on the solenoid shift (fig. 100). In some cases, it is mounted on top of the generator with the cut-out relay. The contact points in the solenoid relay close at 4.3 to 4.7 volts and remain closed while cranking until the battery voltage becomes 2.0 volts or less. After the engine starts, the generator voltage builds up, and as soon as the difference between the generator voltage and the battery voltage is 2.0 volts or less, the relay contact points open.

**63. Bendix drive.**—The Bendix drive is a well-designed starting mechanism used on many cars. This automatic screw pinion shift mechanism is built in two distinct styles: the inboard type, in which the pinion shifts toward the motor to engage the flywheel; and the outboard type (fig. 101), in which the pinion shifts away from the motor. The same general construction is used in both types. A sleeve having screw threads (usually a triple thread), with stops at each end to limit the lengthwise travel of the pinion, is mounted on the extended armature shaft. The pinion gear, which is unbalanced by a

weight on one side, has corresponding internal threads for mounting on this sleeve. The sleeve is connected to the motor armature shaft through a special drive spring attached to a collar pinned to the armature shaft.

*a. Operation.*—When the starting motor is not running, the pinion is out of mesh and entirely away from the flywheel gear. When the starting switch, which may be foot- or hand-operated, is closed and the total available battery voltage is impressed on the motor, the armature immediately starts to rotate at high speed. The pinion, being weighted on one side and having internal screw threads, does not rotate immediately with the shaft, but because of its inertia, runs forward on the revolving threaded sleeve until it meets or meshes with the flywheel gear. If the teeth of the pinion and the flywheel meet instead of meshing, the drive spring allows the pinion to revolve and forces it into mesh with the flywheel. When the pinion gear is fully meshed with the flywheel gear, the pinion is then driven by the motor through the compressed drive spring and cranks the engine. The drive spring acts as a cushion while the engine is being cranked against compression. It also breaks the severity of the shock on the teeth when the gears mesh and when the engine kicks back due to early ignition. When the engine fires and runs on its own power, the flywheel drives the pinion at a higher speed than does the starting motor, causing the pinion to turn in the opposite direction on the threaded sleeve and automatically demesh from the flywheel. This prevents the engine from driving the starting motor. When the pinion is automatically demeshed from the flywheel, it is held in a demeshed position by a latch until the starting switch is again closed.

*b. Advantages.*—Among the chief advantages claimed for this type of motor drive are—

(1) Simplicity of construction.

(2) Mechanism automatic in operation, requiring no action by the operator other than pressing the starter switch.

(3) High starting speed, because the starting motor is permitted to pick up speed before the load is applied.

(4) The engine is given a high cranking torque immediately, thus requiring little cranking and minimizing the demand on the battery.

*c. Disadvantages.*—Among the disadvantages are—

(1) The quick impulse given to the pinion is likely to cause nicking or breaking of the teeth when the pinion does not mesh properly on first contact with the flywheel teeth.

(2) Breakage or nonfunctioning of the pinion latch will cause the pinion to drift toward the flywheel teeth which is likely to cause damage if the engine is running.

(3) All of the starting motor torque is transmitted through the drive spring which will put it under considerable strain.

**64. Reverse current cut-out.**—*a. General.*—(1) The reverse current relay or cut-out is simply an automatic electromagnetic switch connected in the battery charging circuit between the generator and the storage battery of the electrical system. Its function is to connect the generator automatically to the battery when the voltage of the generator is sufficient to charge the battery, and to disconnect them when the generator is not running or when its voltage falls below that of the battery, to prevent the battery from discharging through the generator windings. In these respects the action of the cut-out is very similar to that of a check valve between a pump and a reservoir.

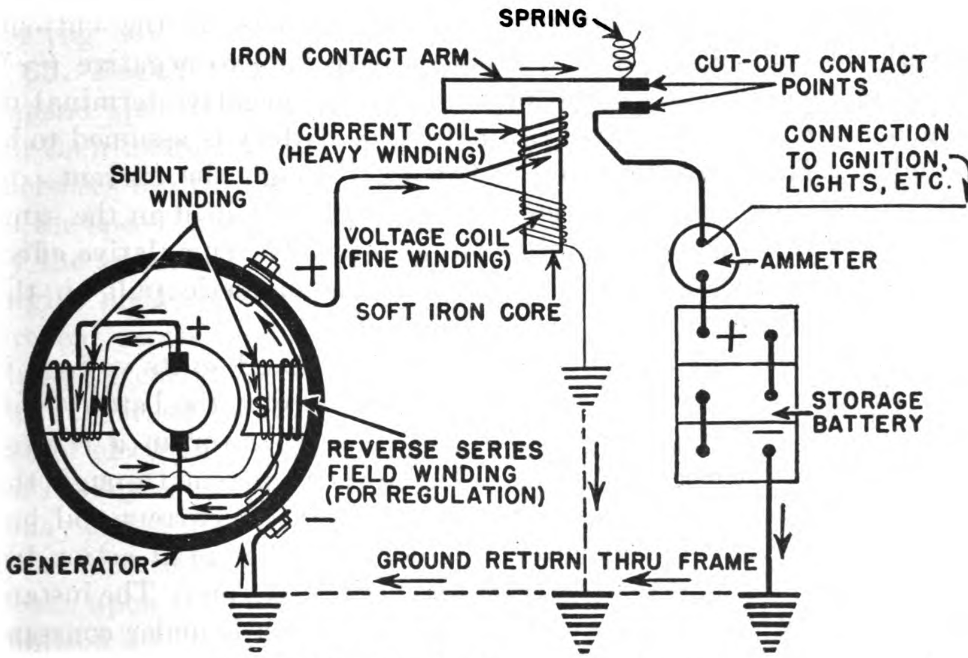



FIGURE 102.—Circuit diagram of a cut-out relay.

(2) A circuit diagram of a typical cut-out is shown in figure 102. It is connected with a generator wound differentially to limit voltage output. The cut-out consists of a soft iron core, a fine shunt winding known as a voltage coil, a heavy series winding known as a current coil, and a set of contact points. One of the contacts is carried on one end of an iron contact arm that is mounted close to the core and held by spring tension, while the other contact is stationary. The contact

points are thus normally held open and are closed only when the magnetic pull of the core on the contact arm is sufficient to overcome the tension of the spring. The spring is adjusted so that the contacts will close when the voltage of the generator has reached from 6½ to 7 volts in a 6-volt system, or 13 to 14 volts in a 12-volt system. These voltages are usually reached at a car speed of from 8 to 10 miles per hour in direct drive or high gear.

*b. Operation.*—(1) The voltage coil, which consists of many turns of fine wire, is connected across the generator terminals to receive the full voltage of the generator. When the generator attains a speed at which it develops approximately 6½ to 7 volts, the core is sufficiently magnetized to overcome the spring tension and to close the cut-out contacts. This completes the circuit between the generator and the battery through the current coil and the contacts. Since the voltage of the generator at this time is higher than the voltage of the battery, a charging current will flow from the positive (+) terminal of the generator, through the current coil and contacts of the cut-out, through the cells of the battery from positive (+) to negative (−), returning through the ground or frame to the negative terminal of the generator. The negative terminal of the battery is assumed to be grounded. The charging current flowing through the current coil flows around the core and creates a magnetic effect in it in the same direction as that produced by the voltage coil. The cumulative effect of these two windings greatly increases the magnetic pull on the contact arm and holds the contacts firmly closed.

(2) When the speed of the generator is decreased so its voltage is lower than that of the battery, that is, below 6 volts, the battery will discharge back through the cut-out and the generator in a reverse direction to the charging current. Any reverse current through the cut-out will cause the current to reverse through the current coil but not through the voltage coil, thus producing a differential action between the two windings that partly demagnetizes the core. The instant the core is slightly demagnetized, the spring, which is under constant tension, pulls the contact arm away from the core and opens the circuit. The contacts will remain open by spring tension until the generator again attains sufficient voltage to close them, thus preventing discharge of the battery through the generator at all times. The ammeter is usually connected as shown in figure 102 so that it will register the amount of current either charging or discharging from the battery. The ammeter then serves as a check on the proper operation of the cut-out since it will indicate when the generator takes the load away from the battery and stops or reduces discharge of the battery.

(3) The air gap between the contact arm and the iron core of the relay has little or no effect upon the voltage at which the cut-out opens, since the spring tension governs this almost entirely, while on the other hand, the voltage at which the cut-out closes is governed by both the air gap and the spring tension.

(4) The normal air gap between the contact arm and the core on the average cut-out should be 0.015 inch to 0.020 inch with the contacts closed. The cut-out should be adjusted as specified by the manufacturer. It is designed to close at a predetermined voltage and to open usually when a small reverse current is flowing. The car speed at which the cut-out opens should be 2 to 3 miles per hour below the closing speed to keep the contact points from "chattering" when the car is being driven at the critical "cut-in" speed. The contact points are usually made of silver, copper, or tungsten and should meet squarely so that good electrical contact is made over the entire contact surface when closed. The cut-out unit is often mounted on top of the generator (fig. 86).

**65. Regulation of the generator.**—*a.* The fields of the generator depend upon the current derived from the armature of the generator for their magnetization. Since the current developed by the generator increases in direct proportion to its speed, the fields become stronger as the speed increases and correspondingly more current is generated by the armature. The extreme variations in speed of the automotive engine makes it necessary to regulate the output of the generator to prevent excessive current overload. On the average motor vehicle, a charging current in excess of 12 to 15 amperes may be harmful to a fully charged battery if continued too long. With the increased use of electrical accessories, generators have been increased in output until they are capable of producing 25 to 35 amperes. Regulation today is therefore more vital than ever before.

*b. Reverse series field.*—(1) Since the output of the generator depends upon the number of conductors in the armature, their speed of rotation and the strength of the magnetic field in which they rotate, varying the strength of this field is the only convenient method of regulation. One of the simplest methods, although not commonly used today, was the use of a reverse series field for differential action as shown in figure 102. A shunt field is connected across the brushes to produce the magnetizing action. Charging current going through the reverse series field, however, has a demagnetizing action, so that as the current increases it tends to restrict the rise of current above a reasonable value.

(2) Such a differentially wound generator has disadvantages which limit its use on motor vehicles. If a break should occur in the charging circuit (excepting normal cut-out operation) thus destroying generator regulation by the series field, the voltage will become excessive, usually resulting in damage to the field and armature winding and to the voltage winding of the cut-out. One outstanding disadvantage is that there is usually no convenient method provided for increasing or decreasing the charging rate. By decreasing the number of turns in the reverse series field, the maximum generator output can be increased. Increasing the number of turns will decrease the output.

*c.* There are at the present time two popular methods of regulating the output of a generator. These are the vibrating relay method and the third brush method. A number of other forms have been used in the past but most of these are now obsolete.

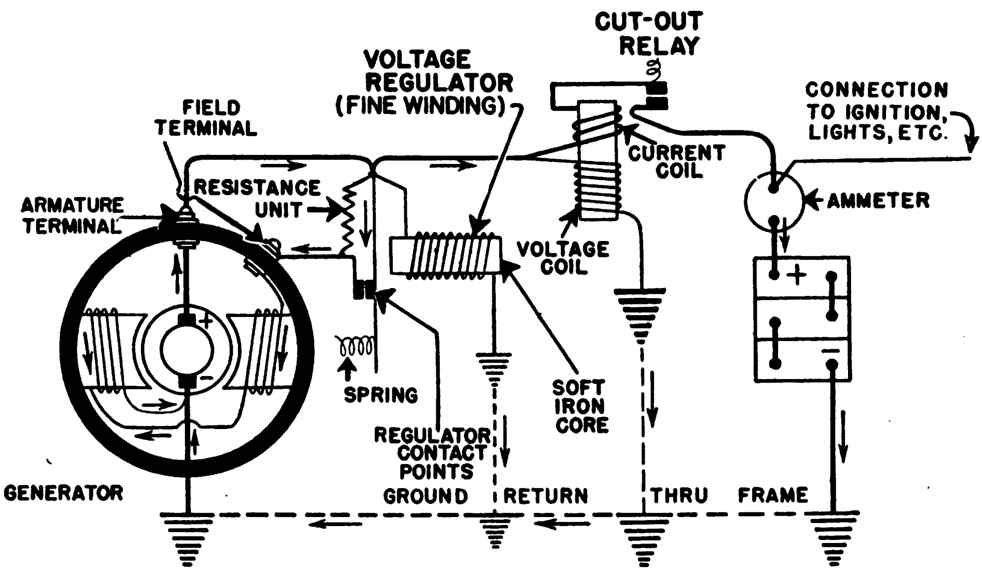



FIGURE 103.—Circuit diagram of vibrating relay current regulator.

**66. Vibrating relay.**—*a. Current regulation.*—(1) The vibrating relay can be used to regulate the current or the voltage, depending on how the regulator coil is connected. A circuit diagram of a typical vibrating relay regulator used for limiting the current from the generator is shown in figure 103. The regulating relay consists of a soft iron core, a heavy winding or current coil around the core, a set of regulator contact points normally held closed by spring tension, and a resistance unit connected across the two regulator contact points.

(2) As the generator speed increases, this vibrating relay controls the current output of the generator by cutting a resistance intermittently in and out of the shunt field circuit as the regulator contact

points open and close due to the varying magnetic pull of the core. The resistance unit is connected in the shunt field circuit but is normally short circuited by the regulator contacts when they are closed, one of which is mounted on a soft iron contact arm to which is attached the spring for holding the points in contact. The generator, when driven by the engine, builds up as a simple shunt wound generator, the shunt field current flowing from the positive (+) brush through the contact points, through the field winding to the negative (−) brush. When the speed and voltage of the generator are increased sufficiently to close the cut-out, the generator will begin to charge the battery, the charging current flowing through the regulator winding. This current flowing through the regulator winding will magnetize the core, which in turn exerts a magnetic pull on the regulator contact arm tending to separate the contacts. When the battery charging current reaches the value for which the regulator is adjusted, the core is sufficiently magnetized to attract the contact arm, overcoming the pull of the regulator spring. This separates the contact points which inserts the resistance unit in series with the shunt field winding and weakens the field strength. This causes a drop in voltage generated in the armature and consequently the charging current decreases. When the current decreases to a predetermined amount, the current coil does not magnetize the core sufficiently to overcome the pull of the spring which then closes the contacts. With the contacts closed, the resistance unit is once more short circuited and the full field strength is restored, causing the charging current to increase again. The regulator will continue to repeat this cycle. Under operating conditions, the contact arm vibrates rapidly enough to keep the generator output constant. As a result, the generator will never charge the battery above a predetermined rate (for example, 20 amperes), no matter how high the speed of the car. This will be true regardless of whether the battery is fully charged or completely discharged.

(3) This method of generator regulation is termed current regulation, since the current output of the generator is used for regulation. It is, therefore, very important that no breaks occur in the charging circuit after the generator reaches a voltage sufficient to operate the cut-out. If a break does occur, no current will flow through the current coil to operate the vibrating points and the generator will build up an excessive voltage at high speeds due to lack of regulation.

(4) In all electrical systems controlled by a vibrating relay, the charging rate of the generator can be easily adjusted. To increase the maximum charging rate, the spring tension on the vibrating contact arm should be increased slightly, and to decrease the maximum

charging rate, the spring tension should be decreased. Care must be taken that the generator output does not exceed that for which it was designed.

*b. Voltage regulation.*—(1) A circuit diagram of a typical vibrating relay voltage regulator is shown in figure 104. Although the construction of this relay does not differ materially from that of the current regulator, the principle of operation is somewhat different. With this regulator, the voltage output of the generator is used for automatic regulation. By comparing figures 103 and 104, it will be seen that the principal difference in the two relays is in the winding of the controlling coil and its connections. In the voltage regulator, the charging current does not flow through the regulator winding. The winding on the core consists of a voltage coil of fine wire, the two ends of which are connected across the generator brushes and in parallel with the battery instead of in series with it as in the current type of regulator. The iron core, regulator points, and resistance unit, however, are practically the same.

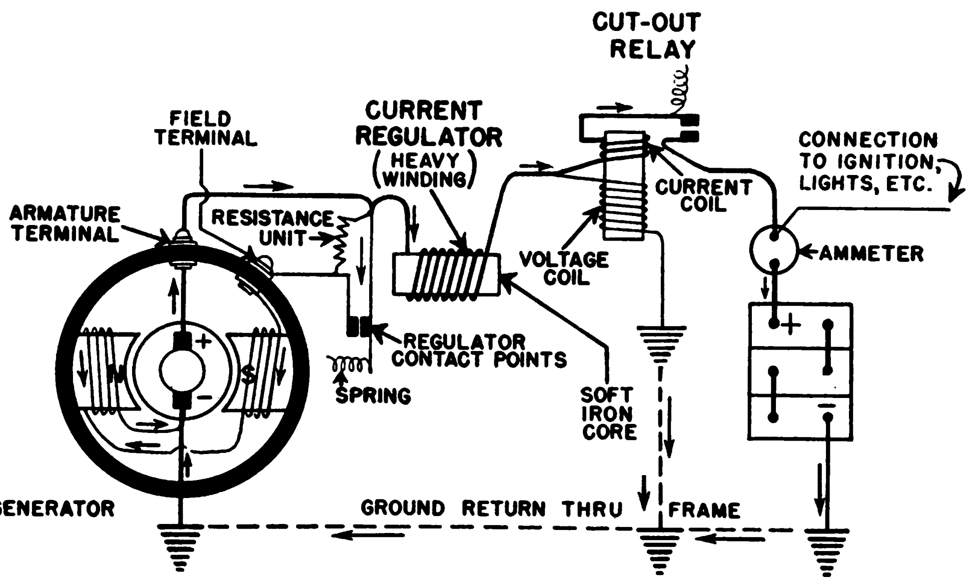



FIGURE 104.—Circuit diagram of vibrating relay voltage regulator.

(2) The current flowing in the regulator coil and the resulting magnetic pull of the core on the contact arm depend upon the voltage developed by the generator. In a 6-volt system, the regulator is adjusted to hold the generator voltage constant at 7.5 to 7.75 volts, usually 7.5. With increasing generator speed, the voltage tends to rise above 7.5 volts. If, however, this value is exceeded by a small amount, the increased magnetic pull of the core on the contact arm,

due to the current flowing in the voltage coil, will overcome the spring tension and pull the contact arm toward the core, thus opening the contacts and inserting a resistance in the generator field circuit. This added resistance decreases the current in the field winding, and the voltage developed by the armature tends to drop below 7.5 volts.

(3) When the voltage drops, the pull of the spring on the regulator contact arm overcomes the magnetic pull of the core and closes the contacts. This short circuits the resistance unit and permits the field current to increase. The cycle of operation is repeated rapidly, preventing the generator voltage from rising above that for which the regulator is set. Should an opening occur in the charging circuit, the regulator will prevent the generator from building up an excessive voltage. If a break occurs in the voltage regulator circuit, regulation of the generator will be lost and an excessive charging rate will result at high speeds.

(4) It is obvious that increasing the tension of the regulator spring will increase the output voltage of the generator. Under no circumstances should the regulator spring tension be increased in an attempt to have the generator charge at a higher rate at lower speeds. The generator cannot begin to charge until the cut-out closes. The closing of the cut-out is independent of the action of the regulator. Increasing the tension of the regulator springs so that the generator will develop a constant voltage in excess of 7.75 volts will usually send excessive current to the battery, overcharging it, or causing the generator to overheat, with the possibility of burning it out.

*c. Charging rate.*—(1) *Current regulator.*—With the vibrating current regulator, the charging current remains constant for any one setting of the regulator, regardless of the condition of the battery. To vary the charging rate according to the battery requirements, the spring tension of the regulator must be adjusted.

(2) *Voltage regulator.*—(*a*) The main advantage of the voltage regulator is that the output of the generator is controlled to a great extent by the amount of charge in the battery. When the generator reaches a speed at which it develops the regulated voltage, there will be no further increase in voltage with increasing speed. The voltage will be maintained constant at all loads and at all higher speeds.

(*b*) During the time the generator is connected to the battery, the difference in voltage between the two is the voltage available for sending current into the battery. In a discharged battery, the difference in voltage between the generator and the battery will be relatively great, so that a comparatively high charging current will pass from the generator to the battery. As the charge continues, the

voltage of the battery increases, so that the difference in voltage between the generator and the battery is continually diminishing. With a fully charged battery, the voltage is nearly equal to that of the generator, and the difference between the two is very slight. As this slight difference in voltage is all that is available for sending current into the battery, the charging current will be small. The charging current, therefore, is variable and depends upon the charge in the battery. In practice, the charging current with the constant voltage regulator varies from a maximum of 25 to 35 amperes for a discharged battery, to a minimum of 4 to 6 amperes for a fully charged battery.

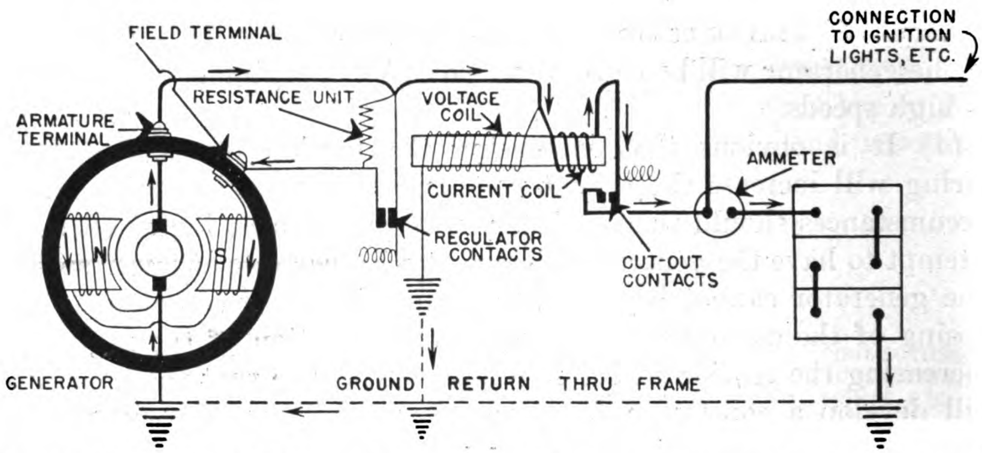



FIGURE 105.—Circuit diagram of combined regulator and cut-out relay (one element).

**67. Combined current and voltage regulation.**—Regulation of voltage only might be satisfactory from the standpoint of the battery, but if the battery were badly discharged the generator might overload itself to supply the heavy charging current. Therefore a current control is usually needed in addition to a voltage control.

*a. Single vibrating contact* (*combined control*).—(1) A circuit diagram of a single vibrating relay for obtaining both current and voltage regulation of the generator is shown in figure 105. The winding of the relay is merely a combination of the other two, the core being wound with both a current and a voltage coil. This construction permits combining the cut-out and the regulator into a single element. The cut-out contacts (fig. 105) are mounted on one end of the core and the regulator contacts on the other end, the two sets of contacts being operated by independent springs. The cut-out is made to function before the regulator by the use of a weaker spring on the cut-out contacts.

(2) The operation of the regulating relay is practically the same as that of the voltage regulator, except that the generator current output is also controlled by the charging current flowing through the current coil. Both the windings carry current around the core in the same direction, the magnetizing force of both combining to operate the regulator and the cut-out contact points. In this manner, the combined characteristics of both current and voltage methods of regulation are obtained. The proper functioning of the relay, however, depends upon the combined effect of both windings. Consequently either high voltage, excess current, or normal limits of both voltage and current would be effective in limiting the output of the generator.

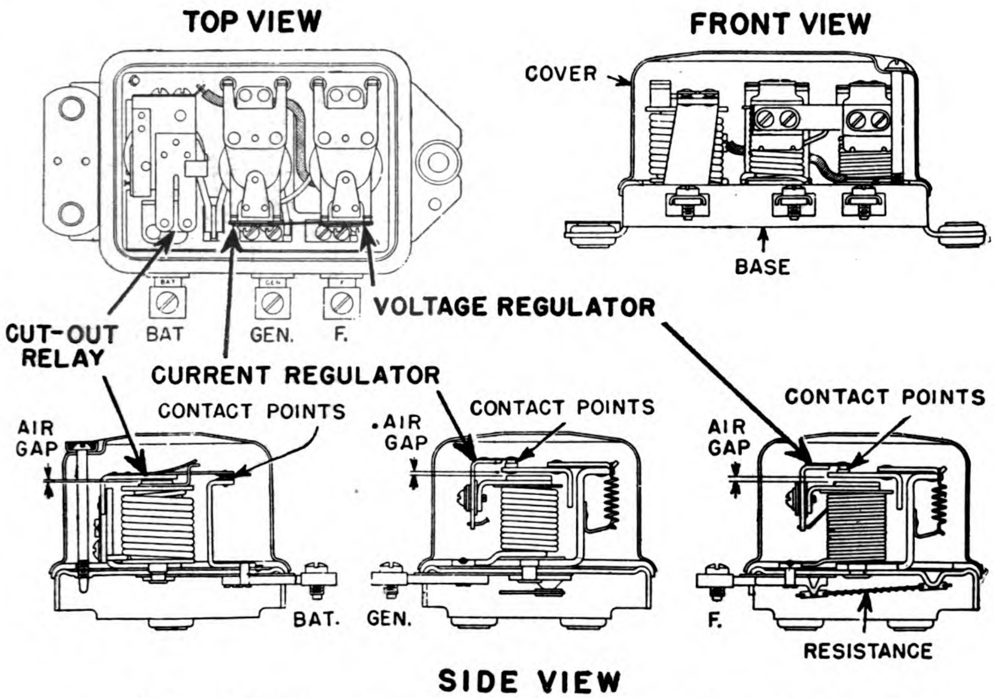



FIGURE 106.—Individual current and voltage regulators and cut-out relay (three elements).

*b. Two vibrating contacts (individual control).*—(1) Instead of combining the current and voltage regulator into one unit on the same core, the present tendency is to use separate elements so that individual adjustments can be made for better control of the generator output. Such a control unit consists of three elements mounted on one base with a common cover (fig. 106). The cut-out, current regulator, and voltage regulator each contain a separate core, coil, and set of contacts.

(2) Operation of the control unit can be understood by following through a typical circuit diagram (fig. 107). Voltage built up by the generator causes a small current to flow from the generator armature terminal *A*, through the current regulator coil and current winding of the cut-out to the cut-out frame which is insulated, and from there through the voltage winding of the cut-out to the ground return. When the generator builds up a voltage which sufficiently magnetizes the cut-out to close its contacts, charging current will flow through the cut-out frame and across the cut-out contacts to the battery. This current flows through the current regulator and will operate its vibrating contacts to limit the current output of the generator. The voltage regulator coil is connected to the cut-out frame so the voltage regulator

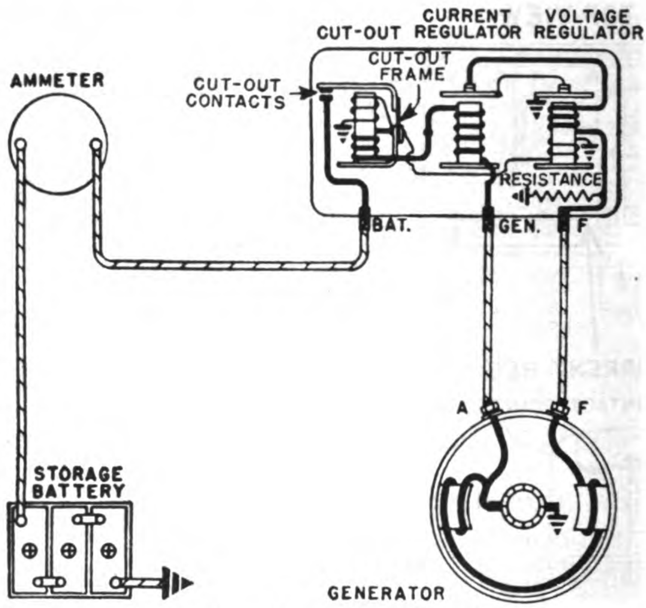



FIGURE 107.—Circuit diagram of individual current and voltage regulator and cut-out relay.

vibrating contacts limit the generator voltage. Sometimes the voltage winding of the voltage regulator is connected to the ignition switch to obtain a close regulation of the battery voltage. Such a connection should be made to the "off" side of the ignition switch so that the voltage coil will not drain the battery when the switch is "off". The voltage regulator also contains a winding in series with the field which aids in operating the voltage regulator contacts to prevent excessive field current.

(3) The field circuit is completed when there is a connection from the field, *F*, terminal of the generator to the ground, as the other end of the field winding is connected to the live brush in the gen-

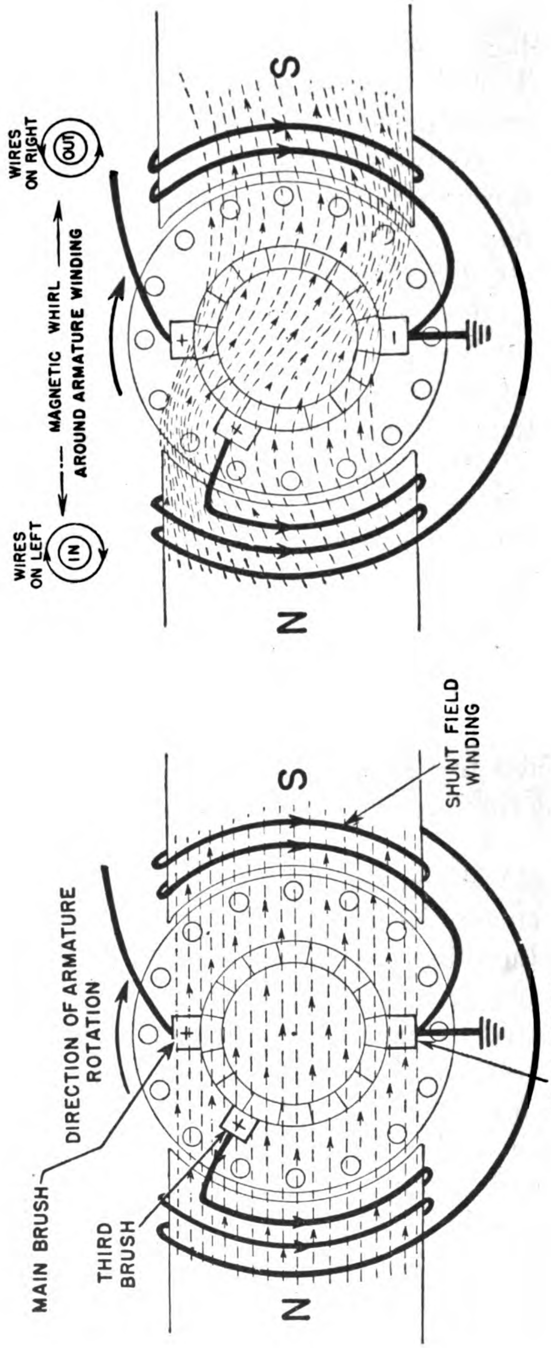
erator. When the generator is not producing enough output to operate the current or voltage regulators, the field circuit is completed through its winding on the voltage regulator and across the current regulator and voltage regulator contacts to the ground. The field then has no outside resistance in the circuit and receives maximum current to help increase generator output. Operation of the current or voltage regulator contacts will open this circuit so that the field current must go through the resistance to the ground which will lower the field strength. Thus normal limits of either current or voltage will regulate generator output. In some regulators, two resistances are used to provide more resistance in the field circuit when the voltage regulator operates than when the current regulator operates. Heavy current output can then be obtained with a pronounced control of the voltage. Preventing the generator from building up too high a voltage is the most important function of the regulator.

**68. Third brush regulation.**—Third brush regulation is much simpler in operation and less expensive to manufacture than other methods of control. Generators with this type of control have an extra brush called the "third brush," located between the two main brushes.

*a. Arrangement.*—Arrangement of a typical two-pole, third brush type of generator is shown in figure 108. One end of the shunt field winding is connected to the third brush, the other end is grounded. Only a part of the total voltage generated is supplied to the field by the third brush.

*b. Operation.*—(1) When the generator is running at a low speed and little or no current is flowing in the armature winding, the magnetic field produced by the field winding is approximately straight through the armature from one pole piece to the other (fig. 108 ①). The voltage generated by each armature coil is then practically uniform during the time the coil is under the pole pieces.

(2) As the generator speed and charging current increase, the armature winding acts like a solenoid coil to produce a cross magnetic field. The magnetic whirl around the armature winding distorts the magnetic field produced by the shunt field winding, so that the magnetism is not equally distributed under the pole pieces (fig. 108 ②). With this distortion of the magnetic field, the armature coils no longer generate a uniform voltage while passing under the different parts of the pole. Although the voltage across the main brushes remains nearly the same, a greater proportion of this voltage is generated by the coils between the positive brush and the third brush than was generated between them when little current was flow-




① Little or no current flowing (low speed). ② Large current flowing (high speed).

FIGURE 108.—Third brush regulation.

ing through the armature winding. This is due to the distortion of the magnetic field which crowds more magnetic lines of force between the positive and third brush.

(3) The coils which connect the commutator between the negative and third brushes are in the region of the weakened field and generate a lower proportion of the voltage. The result is a dropping off of the voltage between the negative and third brushes, which is applied to the shunt field winding, thereby weakening the field strength. As the field strength decreases with increased generator current, the result will be an automatic regulation of the current output.

*c. Charging rate.*—(1) One of the outstanding characteristics of generators with third brush regulation is that the charging rate of the generator increases gradually with each increase in speed up to a car speed of 25 to 30 miles per hour. After this, the charging rate falls off as the speed continues to increase due to pronounced field distortion. At speeds of 50 to 60 miles per hour, the charging rate is approximately one-half its maximum value. This is an advantage, in that the maximum charging rate is obtained at normal driving speeds, while at high speeds, such as during cross-country driving when the starter and lights are seldom used, the decreased charging rate tends to prevent overcharging of the battery and overheating of the generator.

(2) In practically all generators which have third brush regulation, provision is made for changing the charging rate to suit the conditions under which the generator is operated. This can be done by moving the position of the third brush on the commutator. It is evident that the average voltage applied to the field winding will depend upon the number of armature coils spanned by the brushes which collect the field current. Thus, moving the third brush in the direction of the armature rotation increases the average current delivered to the shunt field winding and consequently the output of the generator. Moving the brush against the direction of armature rotation decreases the output. Whenever this brush is moved, care should be taken to see that it makes perfect contact with the commutator.

(3) Since the third brush generator depends upon the charging current flowing through the armature winding to produce the field distortion necessary for regulation, it is obvious that it is current regulated internally (as distinct from external current regulation). It must, therefore, have a complete charging circuit available through the battery at all times, otherwise regulation would be destroyed and excessive field currents would burn out the generator windings. Should the third brush generator be disconnected from the battery for any reason, the generator terminals must be grounded.

**69. Control of third brush generator.**—To guard against the possibility of the third brush generator burning up, a fuze is usually provided in the field circuit. It is placed either in the generator end plate or in the regulator control unit when used. If the battery becomes disconnected, there is a rise in voltage at the generator. This in turn sends an abnormally heavy current through the field winding and this field current burns out the fuze. As soon as the fuze is blown, the field circuit is open and no current can flow through it. The generator then merely turns, producing practically no voltage, and does no harm. The third brush generator provides current regulation only and does not take battery voltage into consideration. In fact, a fully charged battery which has a high voltage will actually get more current from a third brush generator than a battery which is completely discharged, because the high voltage holds up the voltage at the generator, makes the field stronger, and causes the generator output to increase. This, combined with the varying demands of radio sets and other current consuming devices, necessitates more accurate regulation than a third brush generator alone can give.

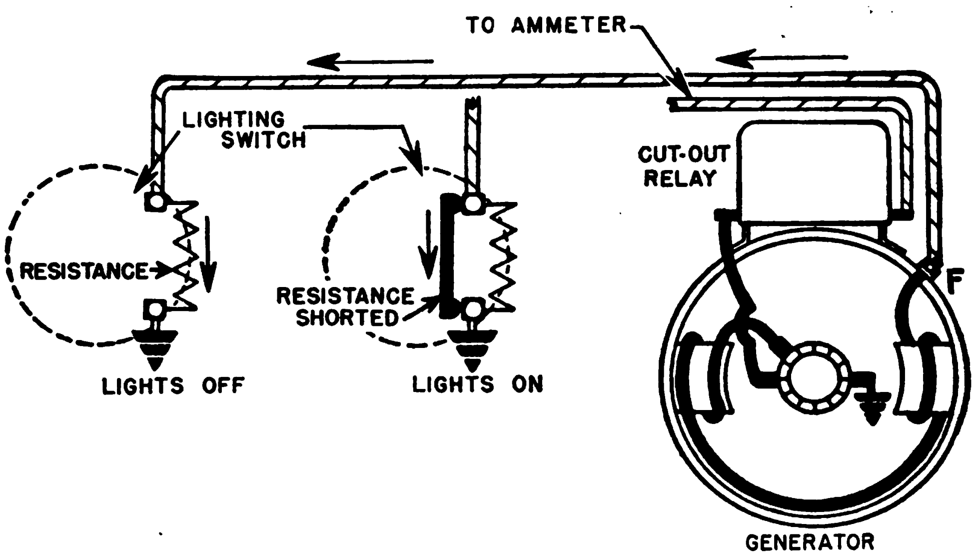



FIGURE 109.—Lighting switch control of third brush generator.

*a. Switch control.*—Practically all systems of regulation provide a means for inserting a resistance in series with the third brush field. A simple way of accomplishing this is shown in figure 109. A resistance is mounted on the back of the lighting switch and connected in series with the field. When the lights are off, the generator output current is limited by the resistance in the field circuit. When the lights are turned on, the resistance is shorted so that the generator

delivers full current to take care of the additional lighting circuit load. This is just a two-step arbitrary system of regulation, however, which will not meet the varied load requirements of a modern vehicle operation.

*b. Step voltage control.*—(1) The purpose of step voltage control is to increase or decrease the output of a third brush generator in accordance with the requirements of the battery and the connected electrical load. It is really a two-stage regulator in which the change from one charging rate to the other is controlled by the generator voltage, which, in turn, is controlled by battery voltage.

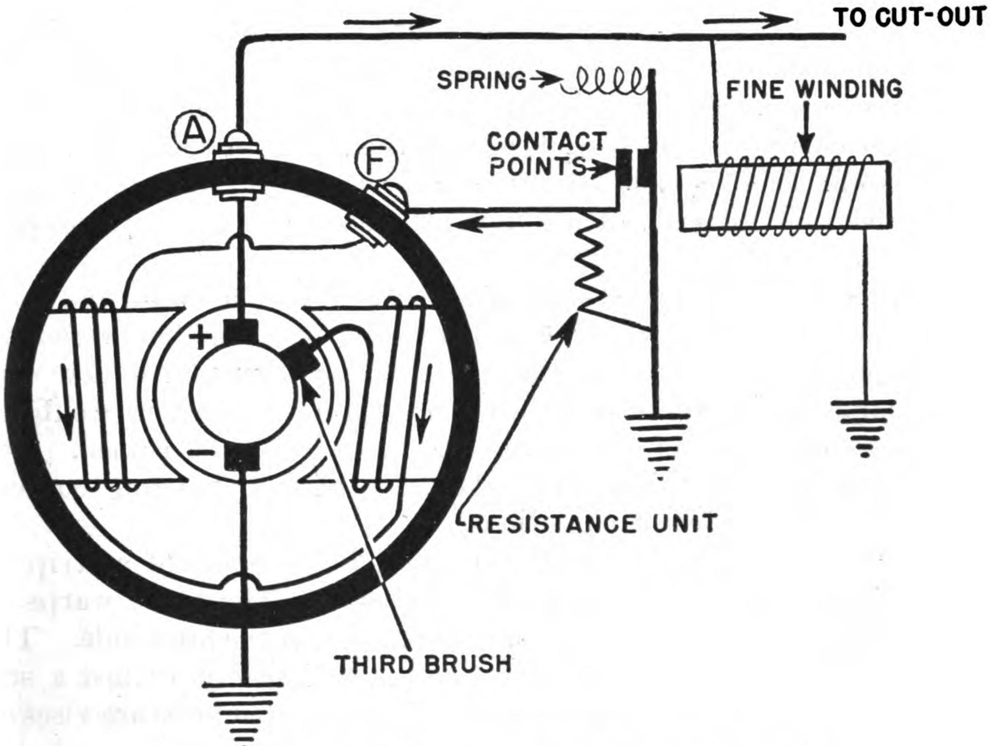



FIGURE 110.—Step voltage control of third brush generator.

(2) A step voltage control unit is shown in figure 110. A fine winding voltage coil, connected to the generator armature terminal *A*, so that it receives the armature voltage, is the controlling element. Contacts are connected in series with the field terminal *F* and have a resistance unit connected across them. When the battery is fully charged, or nearly so, its voltage raises the generator voltage to such a value that sufficient magnetizing current flows through the fine winding on the control unit to pull the contact points apart. When this happens, the resistance across the contacts is connected in series with the field winding to lower the field strength and consequently reduce

the generator voltage and the current output. When the voltage is lowered sufficiently, spring tension will close the contact points and the higher charging rate will be restored.

(3) When there is sufficient electrical load, such as lights, radio, heater, etc., to require a higher generator output, the contact points will close since the load current will lower the generator voltage and the generator will produce its maximum output for the position of the third brush selected and the speed at which it is driven.

*c. Vibrating regulator control.*—A vibrating regulator can also be used with a third brush generator. Such a regulator is controlled by a voltage coil which operates vibrating contacts. When the battery is discharged there is not sufficient voltage to operate the regulator. The generator output is then controlled only by the third brush. As the battery becomes charged, the voltage of the system will increase and more current will be forced through the regulator coil. The regulator points then begin to vibrate, connecting a resistance in the generator field circuit and cutting down the output to a fairly constant value.

*d. Thermostatic control.*—(1) Another type of control for the third brush generator uses a thermostat blade to control the field strength. If the generator is set to give the greatest possible current to take care of demands during the winter, in warm weather the battery would be in a constant state of overcharge and would soon be ruined. The thermostat blade automatically takes care of the changing current demands under different conditions.

(2) It consists of a bimetal thermostat blade made of a strip of spring brass welded to a strip of nickel steel. The blade warps or bends when heated due to the greater expansion of the brass side. The blade is set so that a contact on its end is held firmly against a stationary contact at low temperatures. When the temperature rises to approximately 160° to 165° F., the blade bends and separates the contacts.

(3) The thermostat is connected in the third brush field circuit (fig. 111) so that the full field current passes through the thermostat contacts when closed, permitting full current from the generator. After the engine has been run long enough for the high charging rate to heat the generator, the thermostat contacts open, due to the bending of the thermostat blade, causing a resistance unit across the contacts to be connected in series with the third brush field thereby reducing the current output. The charging rate is reduced approximately 30 percent when the thermostat contacts are opened.

(4) The chief advantages of thermostatic control are that it gives a large battery-charging rate in cold weather when the efficiency of the battery is lower than in warm weather, and also a larger charging rate when the car is being driven intermittently, and the demands on the battery are greater because of frequent use of the starting motor. It also prevents the generator and the battery from overheating in the summer by reducing the charging rate when the temperature rises.

**70. Split series field generators.**—*a.* Generator regulation is sometimes accomplished by means of a split series field. A generator with this method of regulation combines third brush, reversed series (differential), and cumulative compound principles. The series field

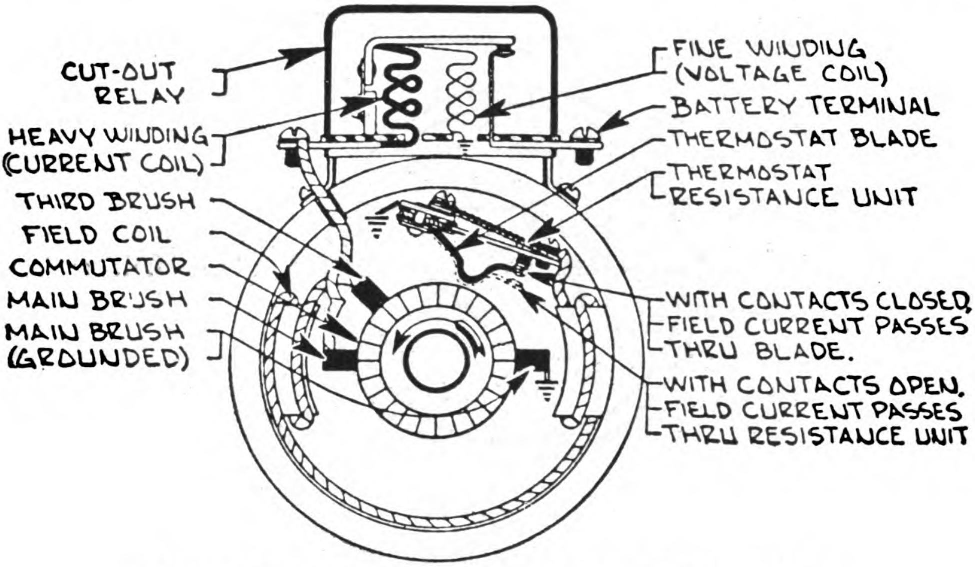



FIGURE 111.—Thermostatic control of third brush generator.

winding is divided so that the generator output is changed according to the load.

*b.* With lights off, no current flows through one part of the series field (marked 1 in fig. 112). The current going to the battery flows through the remainder of the series field (marked 2) in the opposite direction to the shunt field current. This weakens the total field strength, keeping the generator output down for the delivery of a reasonable charging rate.

*c.* When the lighting switch is closed, the entire lighting current flows through section 1 of the series field in the same direction as the shunt field. The strength of the field is thereby increased, giving a higher generator output to take care of the lighting load.

*d.* If the lights are turned on before the generator cut-out closes, the entire lighting current is supplied by the battery. This current

then flows through all of the series field, instead of section 1 only, in the same direction as the shunt field, making the total field strength still greater. This will build up the generator voltage to close the cut-out. The entire current output of the generator, which passes through the cut-out, flows to the center tap of the series field where it divides, part of the current flowing in one direction through to the battery and the remainder to the lights.

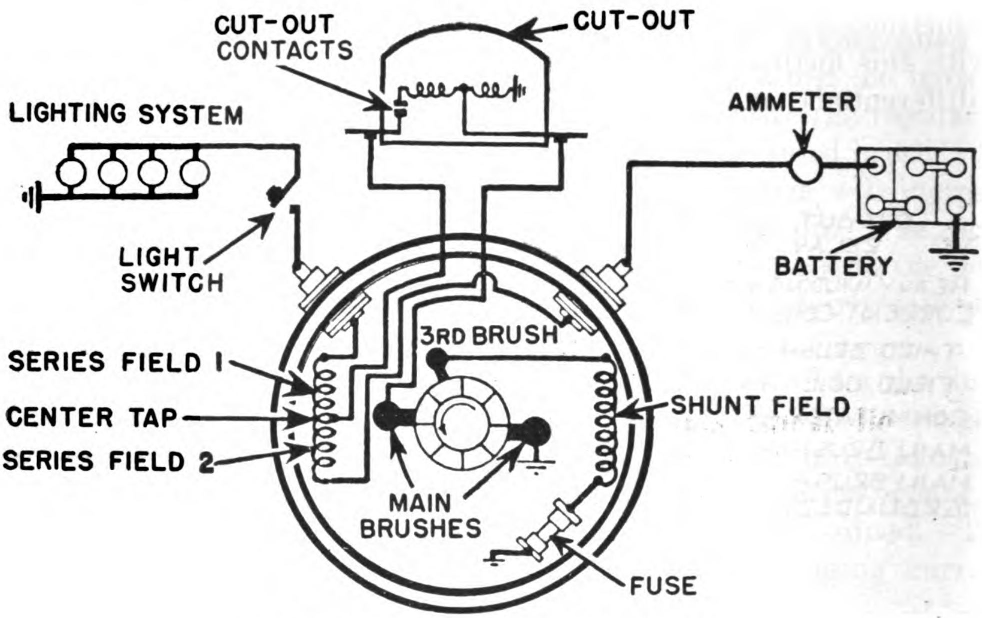



FIGURE 112.—Split series field generator.

*e*. As soon as the cut-out closes, the generator begins to pick up the lighting load. This lessens the drain on the battery and thereby reduces the current flowing through section 2 of the series field. When the generator output just equals the lighting current, the current in section 2 is zero, and as the generator output increases further, current begins to flow in the reverse direction through section 2 to the battery. This tends to weaken the field built up by the shunt winding and section 1 of the series winding. By obtaining the proper relationship between the shunt winding and the two sections of the series winding, results quite similar to those obtained from voltage regulation are secured, and the battery is kept in a charged condition.

*f*. The charging rate of the split series field generator may be adjusted by shifting the third brush as in the regular third brush generator. In some generators of this type separate coils are used for the two sections of the series field. In others the two sections are combined into one coil. Generators of this type do not have standard

connections and must not be confused with the ordinary third brush generator. Neither binding post should be grounded under any circumstances. Proper connections are shown in figure 112.

## SECTION VII

## THE LIGHTING SYSTEM



**71. Motor vehicle lighting.**—*a.* The history of automobile lighting runs parallel with the history of the lighting of houses and buildings; oil lamps and gas lamps having been used in the early automobile. With the development of a satisfactory electrical system, electric lighting has become the standard means of lighting motor vehicles.

*b.* The lighting system as found on most modern motor vehicles consists of the following:

(1) Two head lamps for illuminating the road ahead of the vehicle.

(2) Two dimmer or side lamps for indicating primarily the location of the vehicle when parked.

(3) Tail lamps to illuminate the rear license number plate and to show a red light to the rear.

(4) Instrument panel lamps to illuminate the instruments.

(5) Body lamps, such as dome and step lamps, to light the interior of the vehicle.

(6) Special lamps, such as spot lamps, signal lamps, stop and backing lamps.

(7) Wires and control switches to connect these lamps to the current source.

**72. Lamp bulbs.**—*a.* Small gas-filled incandescent bulbs with tungsten filaments are used on motor vehicles. The filaments supply the light when sufficient current is flowing through them. The lamp bulbs are designed to operate at low voltage, that is 6 or 12 volts

(corresponding to the voltage of the electrical system used), and are wired to operate from control switches located within convenient reach of the driver.

*b*. Most bulbs are provided with a single contact for each filament within the bulb, the current through each filament being completed to the shell of the lamp bulb base. A double filament bulb with the single contact construction is shown in figure 113. Two contacts are provided on the bulb base, each one being connected with one of the filaments. The return from both filaments is to the bulb base shell which is grounded through the bulb socket. Thus there are two separate circuits with two contacts on the base, each of which might properly be termed a single contact, for a grounded circuit.

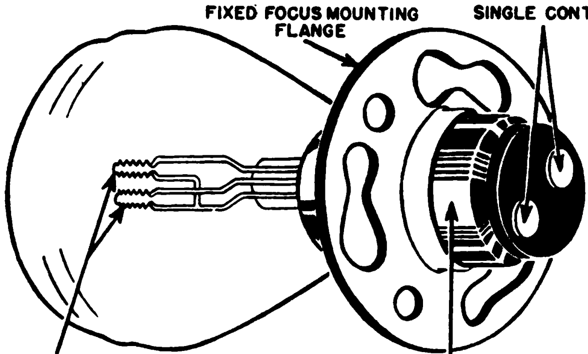


FIGURE 113.—Double filament head lamp bulb.

*c*. Bulbs range in size from the small ½-candlepower instrument panel lamps to the large 50 or more candlepower driving lamps. Inasmuch as the voltage used is low and the current required as a result is high, the filaments are much shorter and stronger than those used for standard house lighting lamps. A short and thick rather than a long and thin filament naturally stands more rough treatment, and this is desirable in the case of a lamp subjected to the vibrations of a motor vehicle. A short filament also provides a concentrated light source that will give a better focus. The candlepower (measure of light intensity) delivered by a bulb depends upon the voltage and amperage consumed. The 2-candlepower bulb consumes 0.43 ampere at 6 volts. The 4-candlepower bulb consumes 0.85 ampere at 6 volts. A bulb similar to the one shown in figure 113 having two filaments, one of 32 candlepower and the other of 21 candlepower, will draw 3.9 and 2.8 amperes.

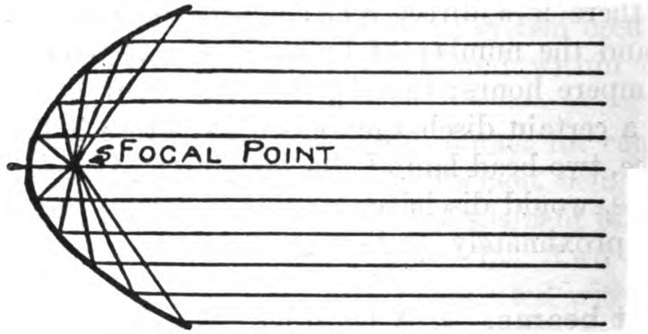
*d*. One reason for the rapid discharge of storage batteries in winter is the increased number of hours during which lamps are used.

Naturally there is a direct relation between the total current con sumption and the number of bulbs used. All storage batteries are rated by ampere hours; that is, the number of hours a battery can be used at a certain discharge amperage before it becomes depleted. For instance, two head lamp bulbs burning at 4 amperes each, a total of 8 amperes, would discharge a storage battery rated at 80 ampere hours in approximately 10 hours unless the generator charged the battery.

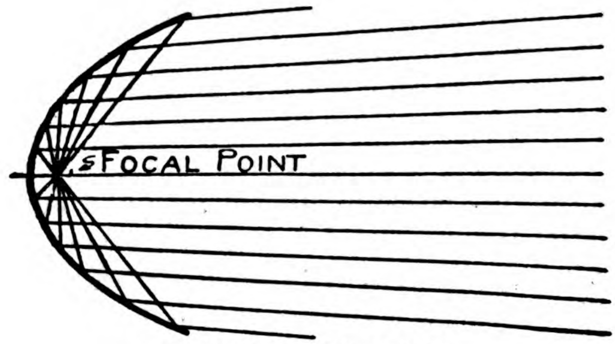
**73. Light beams.**—*a.* A lamp bulb is mounted within a reflector so that the light can be gathered and directed in a confined beam. The best light beam from a bulb is obtained by the use of a parabolic reflector which is the type in general use. There is a focal point near the rear of the parabolic reflector at which the light rays from the bulb are picked up by the polished surface of the reflector and directed in parallel lines to give a beam with a circular cross section. Any other position of the bulb will not give as confined a beam but will tend to scatter the light as shown in figure 114.

*b.* The light beam is distributed over the road by means of a prismatic lens. The effect of a prismatic lens fitted to a parabolic reflector is shown in figure 115. The lens bends the parallel rays from the reflector so that the light is distributed over the road. The vertical flutes of the lens spread the light rays so that the beam is flattened, with the edges thrown out toward the side of the highway.

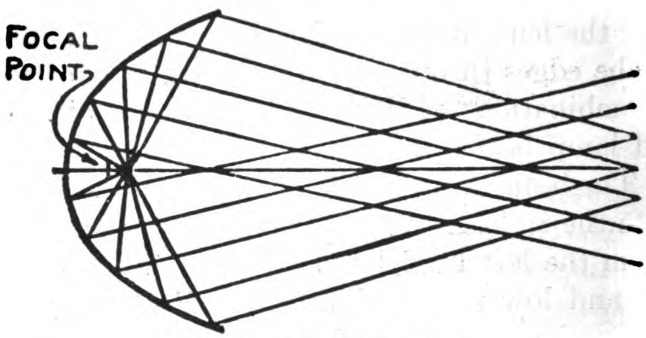
*c.* Many combinations of light beams are possible. One combination of head lamp beams that has been commonly used is shown in figure 116. The beam from the right head lamp (fig. 116 ①) is projected high to the right side of the road and low to the left side, and the beam from the left head lamp (fig. 116 ②) is projected high to the left side and low to the right side. Portions of the beam are deflected lower than other portions due to the design of the lens. When the right and left beams are not the same (fig. 116 ① and ②), the lenses for right and left head lamps are not interchangeable. These beams combine to give a nearly symmetrical beam for driving (fig. 116 ③).




① Bulb at focal point.




② Bulb behind focal point.




③ Bulb ahead of focal point.

FIGURE 114.—Effect of bulb position in parabolic reflector.

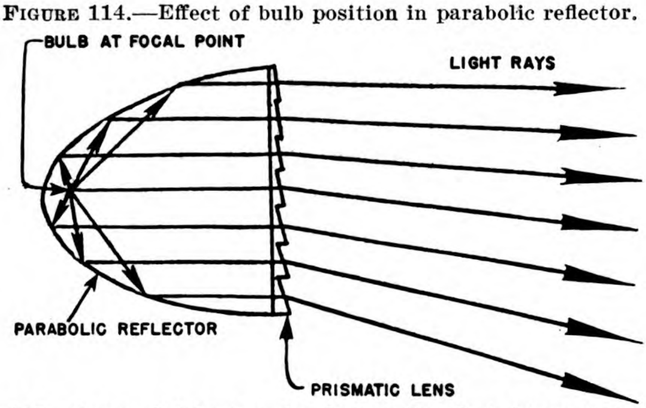
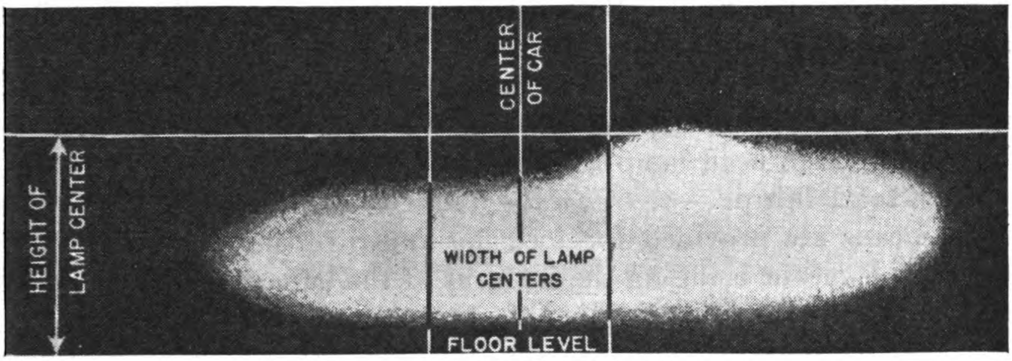
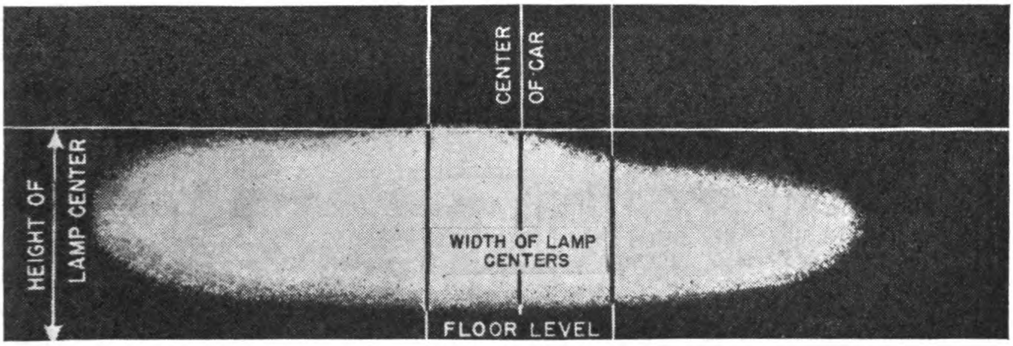


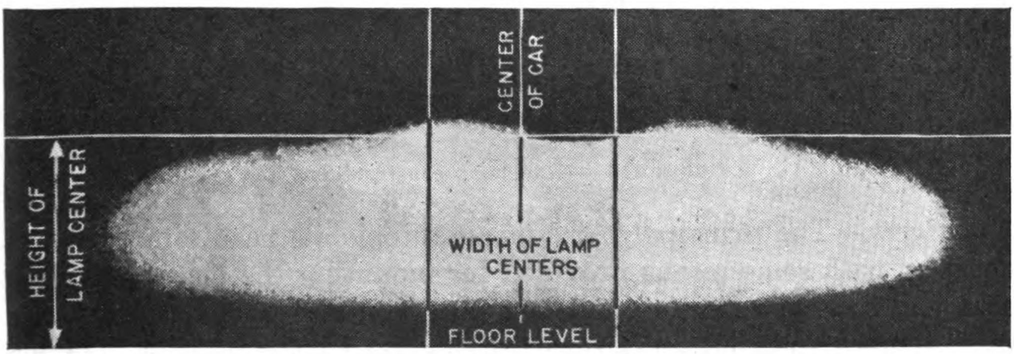

FIGURE 115.—Rays of light from head lamp distributed by prismatic lens.




① Upper beam from right head lamp.




② Upper beam from left head lamp.




③ Combined upper beam from both head lamps.

FIGURE 116.—Head lamp beams.

*d.* With some head lamps, the left-hand lamp illuminates the right-hand side of the road, while the right-hand lamp illuminates the left-hand side of the road. Both lamps together give a symmetrical beam somewhat similar to figure 116 ③.

*e.* The present tendency is toward a spreading beam which illuminates a wide area rather than a concentration of the beam directly in front of each head lamp as shown in figure 116.

**74. Head lamps.**—*a. General.*—(1) In head lamps of the older type, means are provided for focusing and directing the lamp. By focusing is meant bringing the filament of the bulb to the focal point of the reflector; by directing is meant aiming the lamp properly.

(2) Later developments brought into general use a two-filament bulb having its position fixed with respect to its mounting socket at the rear of the reflector so that the filaments remain fixed at the proper focus (fig. 113). To improve the lighting of the roadway, it is necessary only to direct the lamp.

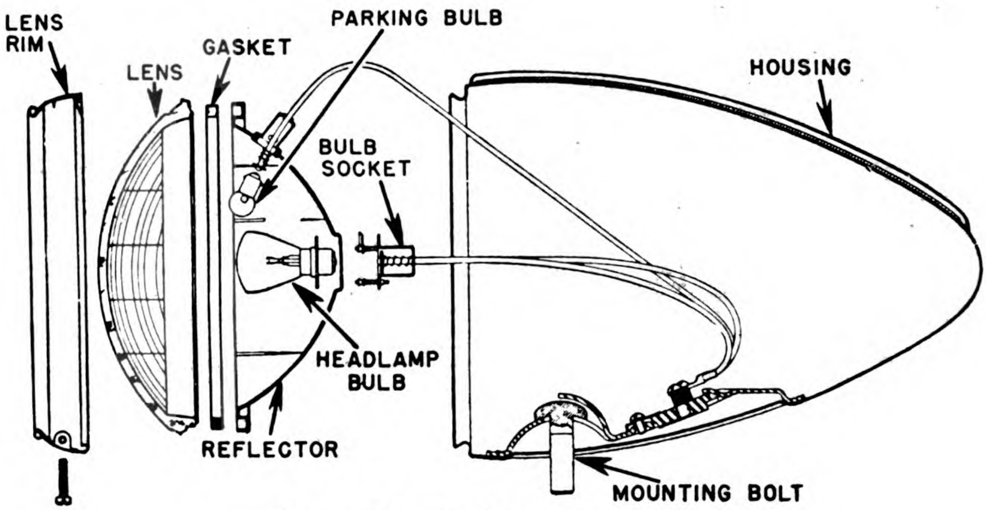



FIGURE 117.—Head lamp construction.

*b. Parts.*—The principal parts of an automobile head lamp are the housing, with some means provided for mounting the housing; lamp bulb and socket; reflector; and lens with rim and gasket to hold the lens in place and to keep dust out of the head lamp interior. These parts are shown in figure 117. One of the bulb filaments, a larger filament, is placed close to the focal point to obtain a good beam for driving on the highway, while a second filament is placed just off the focal point so that a depressed beam is obtained for passing other cars and for city driving. A parking bulb is at times also incorporated within the head lamp as shown.

*c. Sealed beam.*—(1) A superior head lamp that has recently been adopted is the sealed beam head lamp. Not only does it provide far better and more powerful illumination than previous lamps, but it maintains its initial brilliancy with only a slight loss throughout its life. This is because the lens glass is permanently sealed to the reflector, effectively barring moisture which corrodes the reflector and preventing the entrance of dust and dirt.

(2) When a filament burns out, the whole unit must be renewed. However, it has a greater filament life than other type bulbs and requires no maintenance to keep the lamp in good condition.

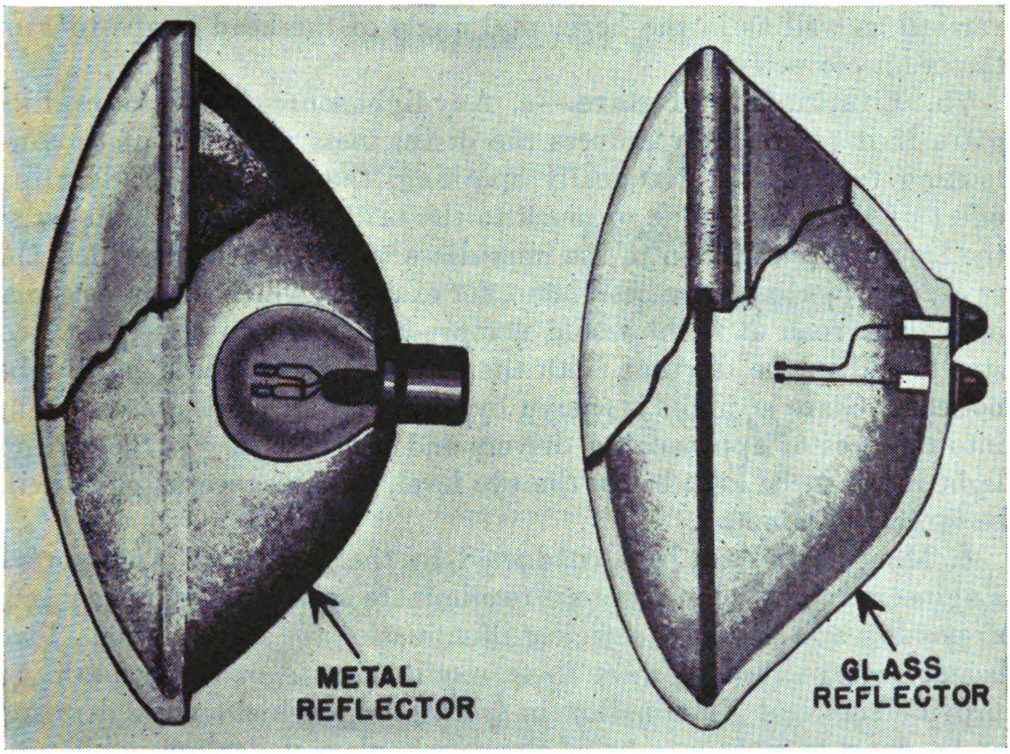



FIGURE 118.—Sectional views of sealed beam head lamp units.

(3) The lamp is made in two types, one with a silver-plated metal reflector and the other with an aluminum surfaced glass reflector. The metal type contains a conventional double filament bulb which is mechanically sealed in the unit, whereas the glass type is its own bulb since the lens and reflector are fuzed together forming a gastight unit with the filaments sealed into the reflector. (See fig. 118.)

(4) Two filaments are provided in the sealed beam head lamp, one furnishing an upper beam for country driving, and the other giving a depressed beam for passing or city driving. With the upper beam

in use, the new lamps provide 50 percent more light than previous 32-candlepower bulbs and also distribute the light more effectively. The upper beam filament requires 40 to 45 watts and the depressed beam filament requires 30 to 35 watts which is more current than that required by the 32-candlepower bulbs. Directing the head lamp to the roadway is the only adjustment required on sealed beam head lamps. Parking lamps are separate.

*d. Mounting.*—The two head lamps are mounted so that their centers are between 32 inches and 42 inches from the ground. The lamps are supported by brackets from either the fender or chassis frame or both and are usually sufficiently adjustable to permit a change in the vertical as well as in the horizontal angle of the head lamps to aim the beam correctly.

**75. Elimination of glare.**—*a.* Any light source is said to produce glare if it appreciably reduces the distinctness of vision of anyone looking toward it. Practically speaking, the blinding or dazzling effect of light is not due so much to the brilliancy of the light as to the lack of illumination in the immediate vicinity through which the rays are projected. The head lamp, for example, which produces glare on a dark road at night would not produce glare on a well-lighted street, and in the daytime with the sun shining it would hardly be noticed. Glare at night is caused by directing strong beams of light into the eyes of approaching drivers and pedestrians. If the strong light rays can be kept below the eye level, the nuisance of glare will be largely eliminated.

*b.* Many tests have been conducted by the Society of Automotive Engineers and by manufacturers to eliminate head lamp glare as much as possible and still have sufficient illumination for safe driving. Two beams are specified to meet these requirements; an upper beam to provide sufficient illumination in front of the vehicle while driving, and a depressed beam to avoid dangerous glare under normal conditions of passing. The driver is responsible for selecting the proper beam. The maximum and minimum intensity at important points of both beams are definitely specified and can be checked with the light intensity or foot-candle meter.

**76. Road illumination.**—Until recently, many of the States had laws prohibiting the use of bulbs of over 32 candlepower in head lamps. Modern development has brought about a radical change in what is considered good road illumination. The high intensity beam of light has given way to the principle of more illumination and lower general intensity. The 32-candlepower bulb is sufficient with a narrow, high intensity beam but with the general flood lighting effect desired today,

a larger light source is necessary. A "sealed beam" head lamp (par. *75d*) has been developed to meet these requirements. With the increased use of high-powered bulbs has naturally come laws enforcing the proper focusing of the lights and the use of dual beam head lamps.

**77. Focusing.**—*a.* When focusing head lamps, it is desirable to place the vehicle on a level surface in front of a focusing screen. The type of adjustment provided on the head lamp must be determined. If the head lamp is not of the fixed focus type, the lamp must be focused first by an adjusting screw usually provided at the rear of the head lamp. The adjusting screw should be turned in or out to secure the most concentrated light on the lighting screen.

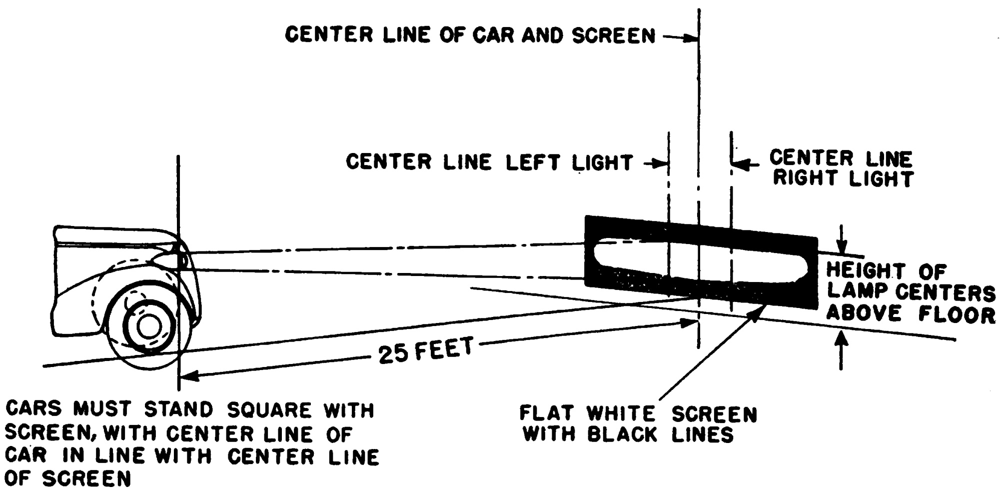



FIGURE 119.—Head lamp aiming chart.

*b.* As most automobiles are provided with fixed focus bulbs, all that is necessary when adjusting the light beam is to have the head lamp properly aimed as shown in the head lamp aiming chart (fig. 119). The car is placed 25 feet from the screen on a level floor. The upper beams from both head lamps should be directed straight ahead. The top of these beams should project to the height of the lamp centers as marked on the focusing screen. If this is done, the beams from the head lamps will always be below the vision of approaching drivers on a level road. The amount of deflection obtained from depressed beams is fixed by the distance between the filaments of the light bulb.

**78. Depressed beam.**—*a.* In order to enable the driver to prevent glare in the eyes of approaching drivers, various methods of depressing the head lamp beam have been introduced.

*b.* Double filament bulbs are commonly used at the present time to obtain both driving beams from one bulb. The bulb is designed so that when it is mounted in the head lamps, one filament will be at the focal point of the reflector and the other filament will be slightly

out of focus so the rays will be deflected downward. Depressing the beam is accomplished by a foot-operated switch which changes the current from one filament to the other.

*c.* Tilting reflectors have been used for obtaining the depressed beam. The reflectors are mounted on a horizontal pivot so that by manipulating a lever on the steering column, the head lamp reflectors may be tilted forward to lower the light beams, thus reducing glare. This methods differs from the other methods in that it merely redirects the light rays and does not reduce either the light intensity or the current consumption of the lighting system for driving on lighted highways and city streets.

*d.* Separate head lamps have been used to obtain the two driving beams, each head lamp having one filament at the focal point. Four head lamps are provided, two being directed for the upper beam and two for the depressed beam.

**79. Switches.**—*a. Head lamp.*—(1) Two head lamp controls are usually provided, one switch being mounted on the instrument panel and another switch on the toe board near the clutch pedal position. A light control switch for instrument panel mounting is usually of the plunger type with three positions. In the first position, with the plunger knob pushed all the way in, head lamps, parking lamps, tail lamps and instrument lamps are all off; that is, the switch is open. In the second or middle position, the parking lamps, tail lamps and instrument lamps are turned on. In the third position, with the plunger knob pulled all the way out, head lamps, tail lamps and instrument lamps are on. With the plunger knob in this position, it is possible to change the head lamps for either upper or depressed beam by pressing the foot dimmer switch on the toe board. Thus it is possible for the driver to shift from the driving beam to the passing beam without removing his hands from the steering wheel. This is highly desirable at high speeds. Usually a small indicating lamp is provided on the instrument panel, which will light when the upper driving beam is on, giving the driver an indication of which beam is being used.

(2) Some manufacturers provide four positions on the instrument panel light switch. Two positions are then provided for the selection of the proper light beam. When the instrument panel switch is in the third or depressed beam position, the foot dimmer switch is inoperative; thus, the driver can maintain the depressed beam when there is difficulty in distinguishing which beam is in use. The foot dimmer switch is operative for the selection of the proper beam when the knob is in the fourth position or all the way out.

(3) The foot dimmer switch is located either to the left of the clutch pedal or between the clutch and brake pedals so that the left foot can be used to operate the switch. The switch is operated by depressing the button to the full depth, which rotates a contactor cam, breaking one contact and making the other. Depressing the button a second time restores the switch to its original position. The switch is designed so that the contacts overlap; that is, one contact is made before the other is broken, so that both beams will not be off at the same time. This eliminates any possibility of head lamps being out while changing beams.

*b. Stop lamp.*—(1) As the function of the stop lamp, mounted at the rear of the vehicle, is to warn any following vehicle that the driver intends to stop, the stop lamp should be so mounted and its brilliance such that it may be readily noticed either day or night. For reason of safety, operation of the stop lamp should also be automatic so that special attention is not required by the driver. Thus, the stop lamp is expected to go on whenever the brakes are applied to slow down or stop the vehicle.

(2) Two types of stop lamp switches have been universally adopted, one for use with mechanical brake systems, and the other for use with hydraulic or air-operated brake systems.

(3) The operation of the stop lamp switch must be coincidental with the operation of the brake pedal. In the mechanical switch, the contacts are closed by a linkage connection to the brake pedal. The hydraulic switch unit is connected directly to the master cylinder so that when the brakes are applied the fluid pressure will operate the switch. The stop lamp switch on air brake systems is operated from the air pressure of the system.

*c. Blackout lamp.*—Vehicles provided with blackout lamps have a special blackout lamp switch which incorporates the operation of the service lamps and blackout lamps in one unit. This switch is shown in figure 120, with its connections to the various units in the lighting system. The plunger knob has three positions: off, blackout lamps, and service lamps. In its second or middle position, the switch turns the blackout lamps on, keeping all other lamps off. The plunger knob cannot be pulled out to its third position until the safety lock button is pushed in. This is a safety feature to prevent any lights visible from above being accidentally turned on during a blackout. In the third position, with the plunger knob pulled all the way out, the service lamps are on and operate normally as described in *a* above. A trailer connection is provided to operate lamps on the rear of the trailer. Trailers are provided with blackout lamps only. These are lit when the switch is in both the second and third positions.

**80. Other lamps.**—*a. Instrument lamps.*—Ordinarily, indirect lighting is used for the instrument lamps, which light whenever the lighting switch is in any of the "on" positions. Many cars are equipped with an instrument panel lamp switch so that the instrument panel lamps can be turned off when desired.

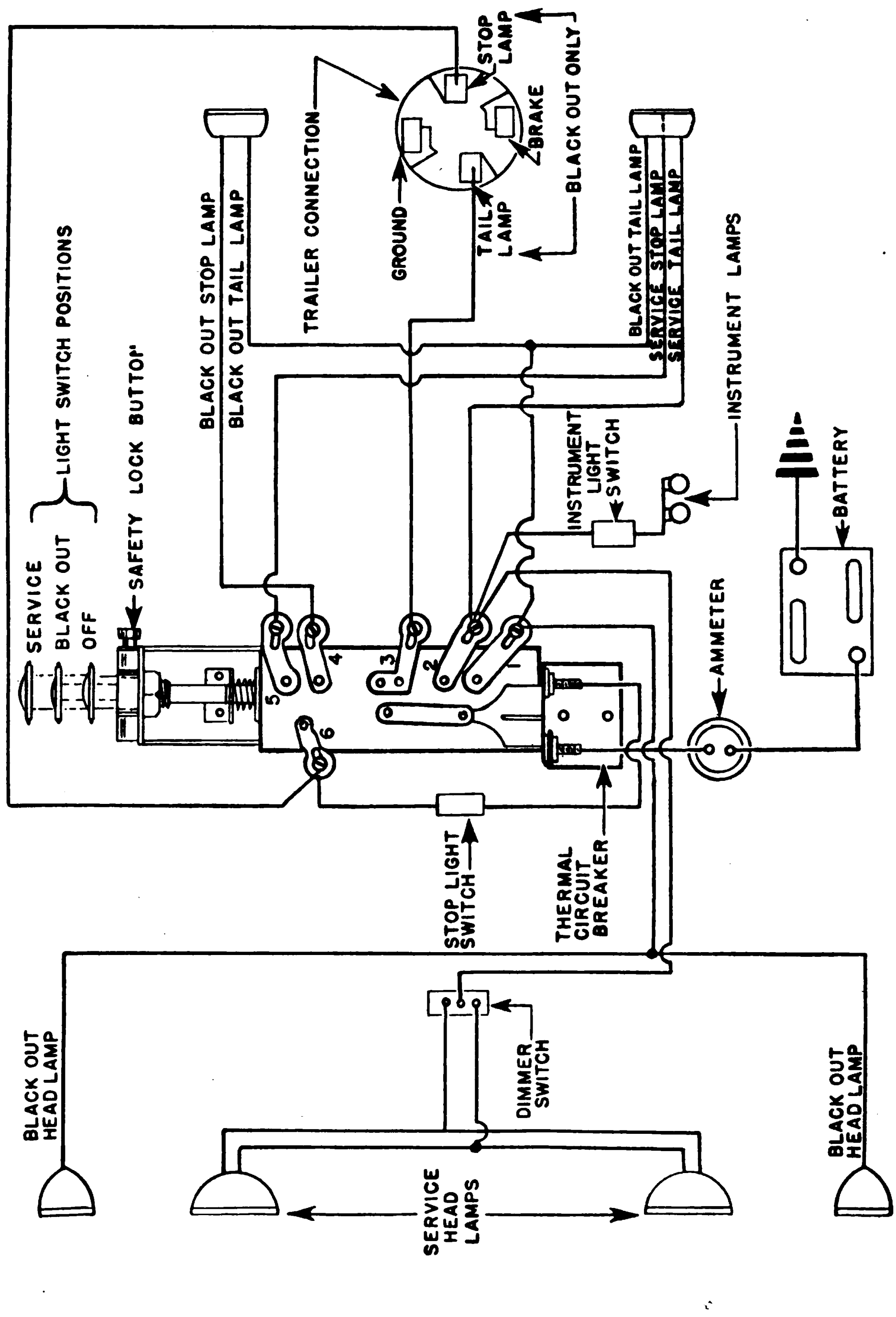



FIGURE 120.—Blackout lamp switch showing its connections.

*b. Dome lamps.*—Practically all closed automobiles make use of dome or tonneau lights. These are ordinarily controlled by means of a switch on a body post near the right-hand door.

*c. Parking lamps.*—(1) The smaller lamps used for parking are sometimes located immediately above or below the main head lamps. The parking lamp housing is then usually constructed as a part of the main head lamp housing.

(2) Side lamps sometimes serve as parking lamps in which case a separate housing is used.

(3) A smaller bulb located within the main head lamp and above the main head lamp bulb has been frequently used to provide a parking light. A 4- or 6-candlepower bulb, or smaller, is used for a parking lamp.

*d. Tail and stop lamps.*—Tail and stop lamps are ordinarily combined, with two bulbs contained in a single housing with a red lens. A larger bulb (about 15 candlepower) is used for the stop lamp and a smaller bulb (about 3 candlepower) for the tail lamp. Tail and stop lamps are sometimes enclosed in a single bulb having a double filament. Tail lamps light whenever the lighting switch is in any of the "on" positions.

*e. Backing lamps.*—Occasionally a backing lamp is used, mounted so as to direct light to the rear of the vehicle. It is arranged and wired so that a switch turns on the lamp when the gear shift lever is put into reverse position.

*f. Spot lamps.*—These lamps are similar in construction to the head lamps. They are designed to project a beam for a great distance ahead and are constructed so that the light can be aimed by the vehicle operator. They are valuable for detecting pedestrians at a safe distance, for observing the condition of the roadway to the sides, and for reading road marking signs.

*g. Auxiliary driving lamps.*—In order to improve the lighting of the roadway without throwing glaring light rays into the eyes of approaching drivers and pedestrians, auxiliary driving lamps are sometimes used. They are designed to be mounted on the front of the car on the head lamp tie rod, on the fender, or on the horns of the car frame. Spot lamps may be used for this purpose and mounted similarly. By using yellow lenses, these auxiliary driving lamps effectively aid the driver in fog. The eye is more sensitive to yellow light and the driver can see objects more readily.

*h. Indicating lamps.*—Buses and trucks are usually provided with lamps to indicate their width or length. These lamps are provided with red, yellow, or green lenses to attract the attention of approach-

ing drivers. The lamps are required by the Interstate Commerce Commission and should be arranged and operated in accordance with their instructions.

*i. Blackout lamps.*—(1) It is a difficult problem to provide a lighting system for night driving that will illuminate the roadway sufficiently to drive at reasonable speeds with a fair degree of safety and at the same time prevent effective observation by the enemy. Intensive study is being given to luminous markers placed on roadsides and on vehicles combined with special driving lights, which illuminate the markers and at the same time are not visible at a distance. The problem of proper night lighting and the use of marking devices depend largely on the selection of drivers. Two men who see equally well in daylight may have quite different relative vision at night. Tests must be made for the selection of men who have acute vision at night. At the present time, small blackout lamps are used. Further research will probably bring other developments.

(2) Blackout lamps are used to enable a convoy to move at night without being observed from the air. These lamps provide sufficient illumination to enable units in a convoy to keep in line while progressing at slow speeds. Two blackout head lamps, two blackout tail lamps, and a blackout stop lamp are provided for this illumination. All other lamps in the car are off when the blackout lamps are lit.

(3) Small housings, somewhat similar to passenger car parking lamp housings, are used with small bulbs that produce subdued lighting. A shutter somewhat like a venetian blind is placed in front of the lens to prevent any light from being projected upward.

## Section VIII

## OTHER ELECTRICAL UNITS

Paragraph



**81. Wiring systems.**—*a.* The purpose of the wiring system is to conduct the electrical energy from the generator and the battery to the

unit requiring it without appreciable loss. Wiring installations in which the chassis frame is used as part of the return circuit are known as ground return systems. The positive side of the battery is usually grounded to the vehicle frame.

*b.* Conductors must be selected that can carry the full load current safely, efficiently, and economically. For this reason, the SAE has specified a recommended practice for wiring systems. It is not advisable to use conductors with a cross sectional size less than that of No. 16 American wire (B and S) gage (0.051-inch diameter) for any circuit regardless of how small the current is. The voltage loss at normal load due to the resistance of a conductor should not exceed 10 percent. Cables for the starting motor should be large enough so that the difference between the voltage at the battery terminals and the voltage at the starting motor terminals should not exceed 0.12 volt per 100 amperes at normal temperatures.

*c.* The National Electrical Code specifies the maximum amount of current that shall be allowed on wires that are commonly used. This code should be followed closely for safe and satisfactory results in any wiring system. The table below gives the maximum current capacity of several sizes of rubber insulated wire. If wires are allowed to carry more than these amounts of current for any length of time, they will heat up to such an extent that the rubber will lose its insulating quality. In cases where long lengths of wires are needed, it is advisable to use larger sizes to prevent large losses due to resistance of the wires.

| B and S gage | Diameter of solid wires in inches | Current carrying capacity in amperes (rubber insulation) | Circuits ordinarily used in— |
|---|---|---|---|
| 16 | 0. 0508 | 6 | Gages, small lamps. |
| 14 | . 0641 | 15 | Stop lamps, ignition. |
| 12 | . 0808 | 20 | Head lamps, ammeter. |
| 10 | . 1019 | 25 | Horns, generator. |
| 8 | . 1285 | 35 | Generator. |
| 1 | . 2983 | 100 | Starter. |
| 0 | . 3250 | 125 | Starter. |
| 00 | . 3648 | 150 | Starter. |

*d.* Terminals on other than starting motor cables should be clamped to the insulation and soldered to the conductors. SAE standard ter-

minals or lugs should be used on starting motor cables. Insulated conductors should, where possible, be grouped together and protected by a nonmetallic tape or braid covering capable of withstanding severe abrasion, except where otherwise protected or not in contact with metal surfaces. To provide this protection and also to provide a compact installation, much of the wire is usually included in a harness made of a braid covering with only the ends of each wire exposed close to its point of connection. Typical harness used on a motor vehicle is shown in figure 121 with the various terminals provided to connect the wires to the proper electrical units. Where the electrical unit requires a long lead from the harness, an insulated connector is used to join the wire included in the harness to a long single wire leading to the electrical unit. Terminals which snap into the connector are soldered to both wires. Wiring should be properly supported by cleats at intervals. The edges of all holes in metal members through which conductors pass should be rolled or bushed with rubber bushings (grommets).

*e.* Ground return connections should be made to the chassis frame or engine. In cases where the engine or body is mounted on rubber or other insulation, it should be grounded to the frame by a good flexible connection such as copper braid. The surfaces to which the terminals are grounded should be clean and free from rust or paint.

*f. Insulation.*—(1) With the ground return system in use, the least fault in the insulation of the wires or cables will cause difficulty. A surprisingly large part of all motor vehicle electrical trouble is due to wiring failure. However, the wiring system is simple and repairs are rather easily made. Finding a defect is perhaps more difficult than making the repair. With an understanding of the value of proper insulation, the mechanic or operator can prevent much trouble by giving the wiring system reasonable attention and care.

(2) Oil, dirt, and water tend to rot the insulation of the wires and cables. Consequently, it is well to keep them clean. When breaks do occur, it is a small matter to bind the broken insulation with friction tape or with rubber tape first and friction tape over it. Pinching wires under the body or between metal parts of the car results in trouble as soon as the wires have had the insulation worn away by the vibration of the car. If the wire insulation has been worn through so that a live wire comes in contact with the frame of the car, this will result in a ground or short circuit and current will be wasted which may discharge the battery. Fire is a far more serious and not infrequent result of a short circuit.

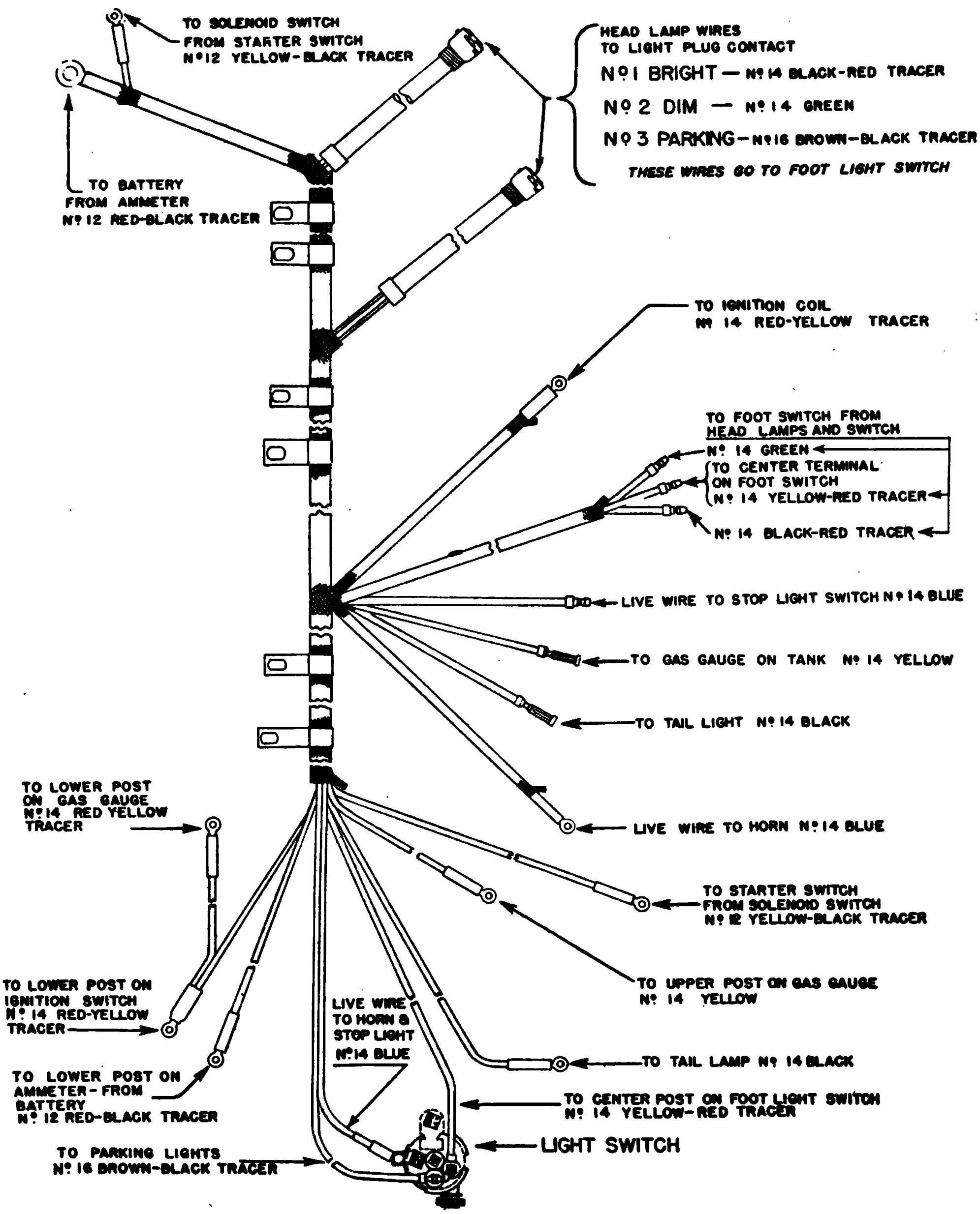



FIGURE 121.—Typical wiring harness.

(3) High-tension wires or cables are put to the severest test. Besides having to carry 15 or 20 thousand volts they are subjected to the heat of the engine. Heat tends to crack the rubber insulation so that the high tension spark may leap to a ground rather than go to the spark plug. It is not advisable to repair high tension wires with tape; they should be renewed occasionally. The higher the voltage or pressure in a wire the greater the necessity for good insulation. Six volts will not jump air gaps and go out of its path

even though the insulation is very thin, but the high voltage in the secondary circuit will jump a ½-inch air gap quite readily.

**82. Wiring diagrams.**—*a.* Figure 122 is representative of the wiring diagrams used by the automobile industry to illustrate the electrical system of a motor vehicle. The main point to be remembered in tracing circuits according to wiring diagrams is the fact that no attempt is made to show the exact position or proportional lengths of the wires. Switches, generators, starting motors, etc., are represented by conventional signs. The contacts and circuits through the various electrical units are not always indicated.

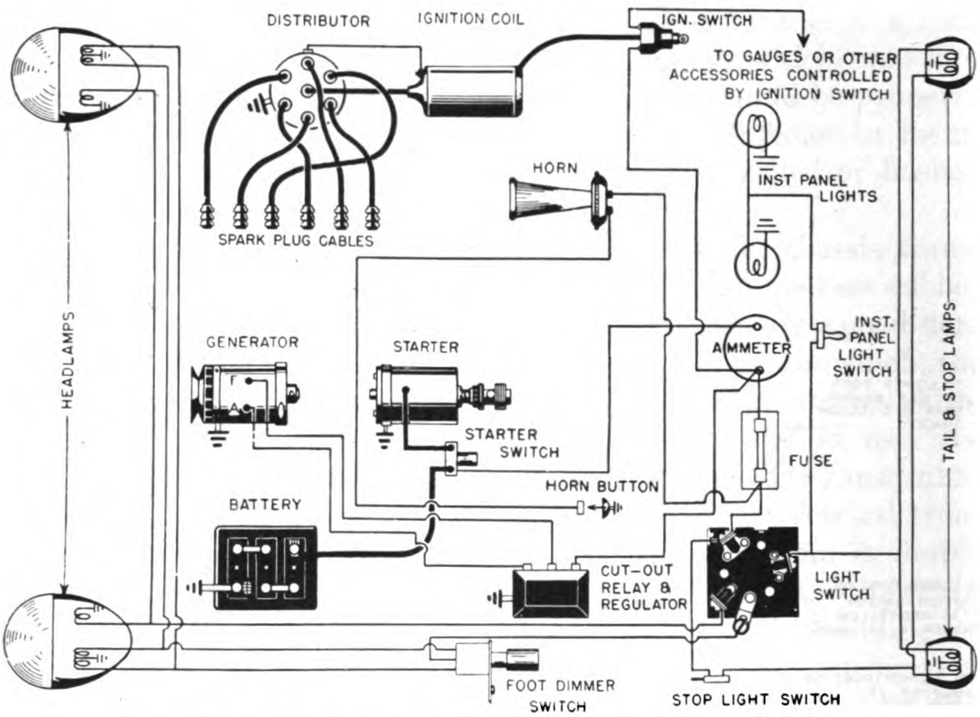



FIGURE 122.—Wiring diagram of electrical system on a motor vehicle.

*b.* Wiring diagrams usually show the joining of two wires with a dot at their juncture and make use of the hopover (a semicircle) where two wires cross without joining. The main function of the wiring diagram is to assist in tracing the circuits of an electrical system and to show the wire leads and how they are connected to the various units in the system.

**83. Wiring color code.**—To simplify the installing and connecting of wiring in motor vehicles and to afford a positive means of identifying the circuits, a wiring color code recommended by the

SAE is usually observed by manufacturers. The recommended color codes for passenger cars, buses, and trucks are listed below. Representative diagrams of the size and color of the wiring used for the various circuits on the motor vehicle are shown in figure 123.

*a. Passenger car wiring color code.*

RED (unprotected (unfuzed) live wires)

Generator to cut-out or regulator.
Cut-out or regulator to ammeter.
Ammeter to overload breaker or fuze.
All other unprotected live wires.

RED WITH YELLOW TRACER

Low tension or primary ignition.

RED WITH BLACK TRACER

Ammeter to battery.

YELLOW (protected (fuzed) live wires)

Horn feed wire.
Signal lamp switch feed wires.
Body lighting switch feed wires.
Protective devices to lighting switches.
All other protected live wires.

BROWN WITH BLACK TRACER

Lighting switch to junction block (parking lamp).
All ground connections (except battery ground).

BLACK

Lighting switch to tail lamp.

BLACK WITH RED TRACER

Bright head lamps (or upper beam).

GREEN

Dim head lamps (or lower beam).
Signal lamps (switch to lamp).

*b. Motor coach and truck wiring color code.*

RED (unprotected (unfuzed) live wires)

Generator to cut-out or regulator.
Cut-out or regulator to ammeter.
Ammeter to battery.
Ammeter to overload breaker or fuze.
Low tension or primary ignition.
All other unprotected live wires.

YELLOW (protected (fuzed) live wires)

Horn feed wire.
Signal lamp switch feed wire.
Body lighting switch feed wires.
Protective devices to lighting switches.
All other protected live wires.

BROWN WITH BLACK TRACER

Generator cut-out or regulator to ground.
All ground connections (except battery ground).

BLACK

Bright head lamps (or upper beam).
Body lamp feed wires (switch to lamp).

BLACK WITH RED TRACER

Dim head lamps (or lower beam).
Tail lamp.

GREEN

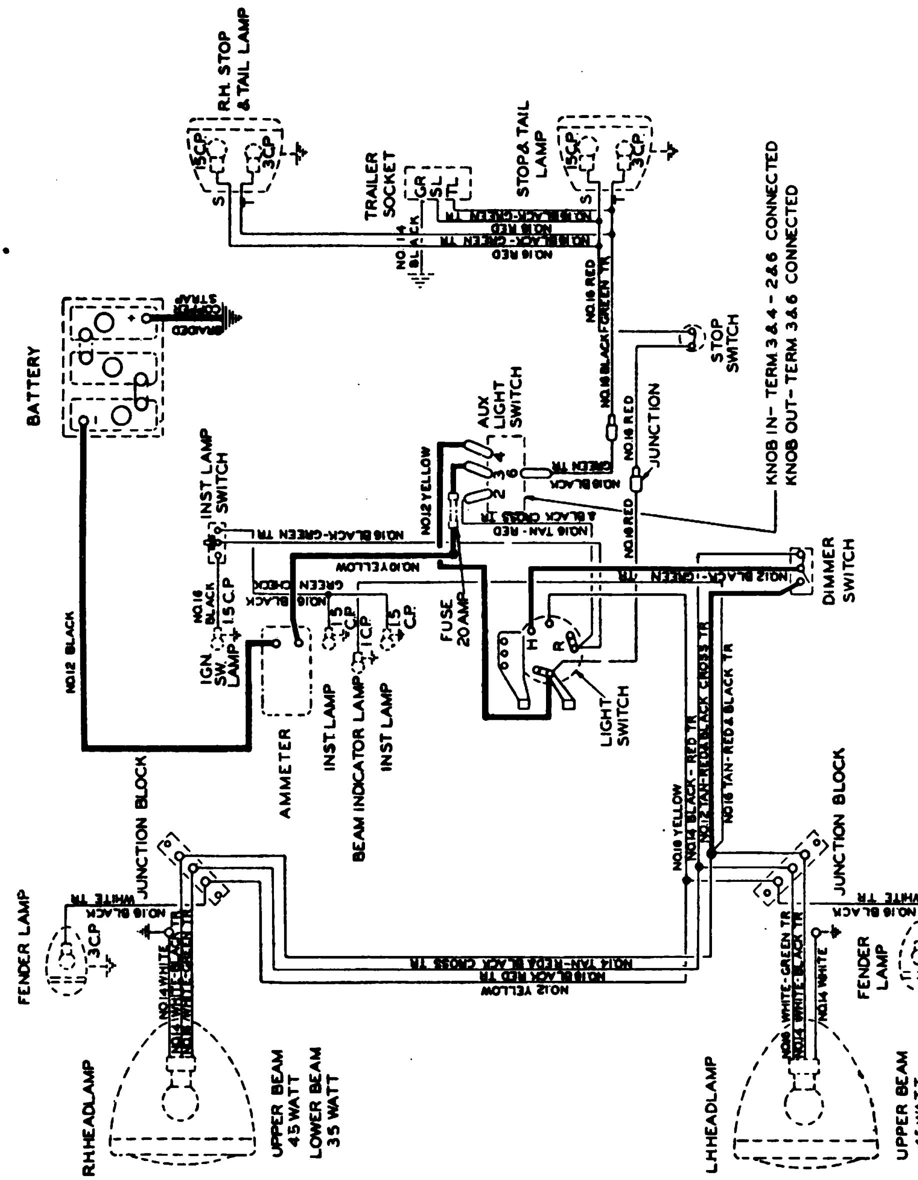
Signal lamp (switch to lamp).
Signal lamp (to indicator or pilot).

**84. Overload breakers.**—Besides limiting the current by current regulation (sec. VI), the battery and wiring should be protected against excessive loads which might occur due to shorts or grounds in the wiring system. Such protection may be secured by a current limiting circuit breaker or a single fuze. The location of an overload breaker in the electrical system is shown in figure 124.

*a. Circuit breaker.*—(1) The circuit breaker is a protective device designed to open the circuit when a current in excess of what it is intended to carry passes through its winding. All current for lights and accessories pass through it. It is similar in construction to the cut-out, but opens the circuit rather than closes it. If there is a ground or other trouble in the circuit, the rush of current will start the circuit breaker vibrating and in this way it indicates that there is something

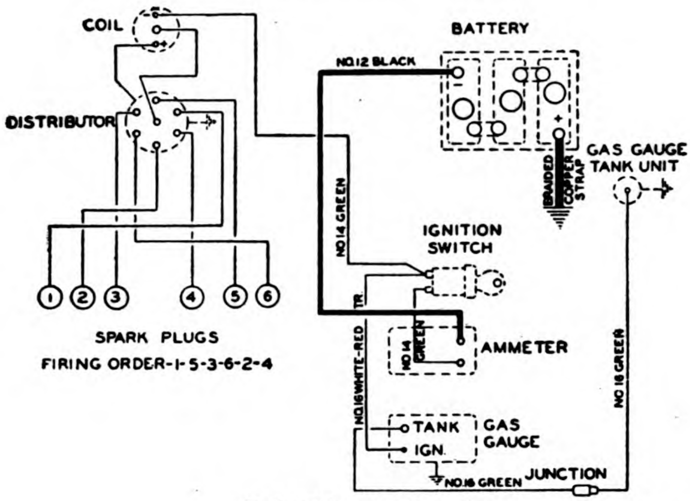
wrong in the system. The device breaks the circuit at about 25 amperes but after opening, allows only about 5 amperes to pass through, which keeps it vibrating. Thus the circuit breaker protects the battery from rapid discharge when trouble develops. The circuit breaker will continue to vibrate until the trouble is found and corrected.

(2) In all types of circuit breakers, the short circuit must be removed before the breaker can be reset. The short circuit can be easily located by disconnecting each circuit separately until the circuit breaker stops vibrating.

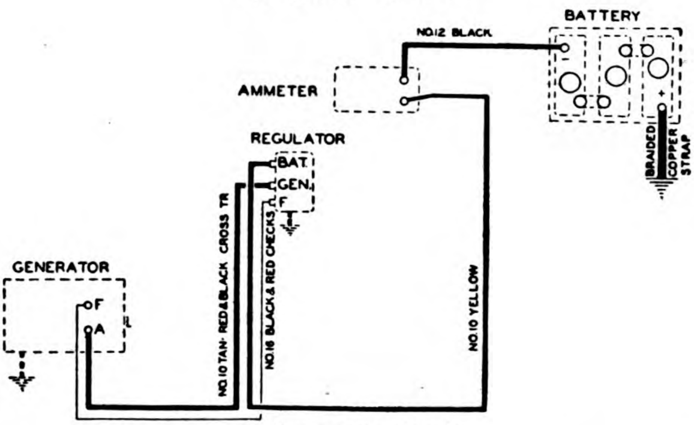



① Lighting system.

FIGURE 123.—Wiring diagrams of electrical circuits on a truck showing typical wire size and color.




② Ignition system.




③ Generator circuit.

**Figure 123.**—Wiring diagrams of electrical circuits on a truck showing typical wire size and color.—Continued.

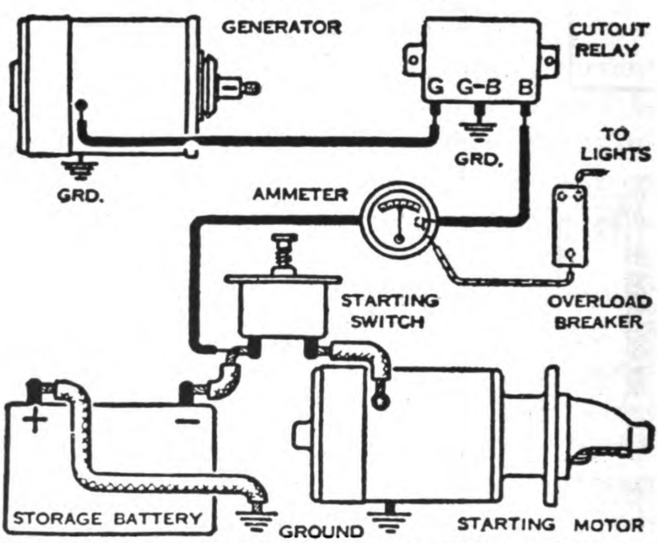



**Figure 124.**—Simplified wiring diagram showing location of overload breaker (circuit breaker or fuze) in electrical system.

(3) Some automatic breakers do not vibrate but have a "telltale" light placed across the contacts. This light, generally placed where it is visible by the operator, is protected by a resistance. When the circuit breaker contacts are opened by excessive current, the light flashes on. There is generally sufficient current flowing through the relay coil with the lamp in series to hold the contact arm of the circuit breaker down until the short is removed. After removing the short, it may be necessary to turn off all lights for an instant to permit the relay to reset itself and extinguish the "telltale" light.

*b. Fuze.*—A more common method of protection is to use a fuze in the lighting circuit. Whenever there is an excessive current through the lighting circuit, the fuze will burn out and open the circuit. The short circuit should be removed before the fuze is replaced. The disadvantages of using a fuze are that the circuit must be traced to locate the trouble and that a burned-out fuze must be replaced. However, it provides much cheaper protection to the system.

**85. Instruments.**—The instrument panel is usually placed so that the instruments may be easily read by the driver. They inform the driver of the approximate speed, engine temperature, oil pressure, rate of charge or discharge of the battery, amount of gasoline in the supply tank, distance traveled, and the time. Certain controls are frequently mounted on the instrument board, such as freewheeling, throttle, spark, choke, starter, heater, windshield wiper, and other controls. Switches, ammeter, and gasoline gage have a definite connection with a study of the electrical system.

*a. Ammeter.*—(1) The ammeter is used to indicate the amount of current flowing to and from the battery. It does not give an indication of total generator output because other units in the electrical system besides the battery are supplied by the generator. If it shows a 10-ampere discharge, it indicates that a 100 ampere-hour battery would be discharged in 10 hours; that is, 10 amperes flowing for 10 hours.

(2) Current flowing from the storage battery to the starting motor is never sent through the ammeter, since the great quantities used (200 to 600 amperes) cannot be measured on an instrument of such limited capacity. In the usual type of ammeter, all the current flowing to and from the battery, except for starting, is actually sent through a coil to produce a magnetic effect which deflects the ammeter needle in proportion to the amount of current. Thirty amperes is about the maximum capacity for this coil.

*b. Fuel gage.*—Most fuel gages are electrically operated and composed of two units; the indicating unit which is mounted on the

instrument panel, and the tank unit which is mounted on the gasoline fuel tank. The ignition switch is included in the fuel gage circuit so that the electrical fuel gage operates only when the ignition switch is "on." Operation of the electrical gage depends on either coil action or thermostatic action. Fuel gages operated mechanically are discussed in TM 10-550.

(1) *Coil type.*—(*a*) The electrical circuit for a fuel gage is shown in figure 125 in which the coil type indicating unit is illustrated. Indication of the fuel level is accomplished by the variation in magnetic effect of two coils on a pointer caused by a change of resistance in the tank unit. The rising or falling float in the fuel tank moves the arm of a rheostat or variable resistance.

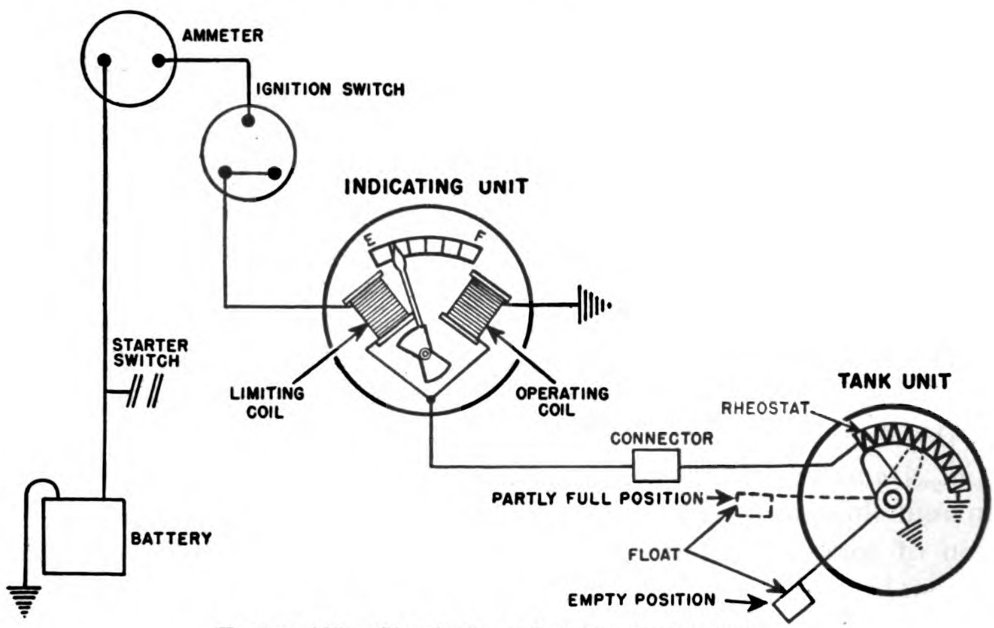



FIGURE 125.—Circuit for coil type gasoline gage.

(*b*) Current from the battery passes through the limiting coil to the common connection between the two coils, which is the lower terminal on the indicating unit. At this point, the current is offered two paths, one through the operating coil of the indicating unit and the other over the wire to the tank unit. When the gasoline tank is empty, the grounded rheostat arm on the rheostat cuts out all the resistance in the tank unit. Most of the current will pass through the tank unit circuit because of the low resistance and only a very small portion through the operating coil of the indicating unit. As a result, this coil is not sufficiently magnetized to move the indicating pointer in the indicating unit which is held at the empty position by

the limiting coil. If the gasoline tank is partly full, the float of the tank unit rises on the surface of the gasoline and moves the rheostat arm over the resistance, putting resistance into the tank unit circuit as indicated by the broken lines in figure 125. More current will then pass through the operating coil to give a magnetic pull on the pointer, which overcomes some of the pull of the limiting coil. When the tank is full, the tank unit circuit contains its maximum resistance to the flow of current. The operating coil will then receive its maximum current and exert a maximum pull on the pointer to give a full tank reading. As the tank empties, the operating coil loses some of its magnetic pull while the limiting coil still has approximately the same pull so that the pointer is pulled toward a lower reading.

(*c*) This type of gage consumes very little current, about 1/8 ampere. Since the operation of this gage depends on the difference in the magnetic effect between two coils, variations in the battery voltage will not cause an error in the gage reading.

(2) *Thermostatic indicating unit type.*—(*a*) The indicating unit, with the dial removed, of one type of thermostatically operated electric fuel gage is shown in figure 126. This gage operates by the electrical heating of bimetal thermostat blades. The blades *A* and *B* are heated by the insulated resistance wire wound around them. Current enters the fuel gage at the center terminal on the back of the gage. From there it passes through the contact points *E*, then up the blade *C*, and down the blades *A* and *B* to a point near the end of each blade where the resistance heater wire is welded to them. It then passes up through the resistance wire on each blade to the terminals marked Nos. 1 and 2. These terminals are both connected by separate wires to each end of a rheostat in the tank unit.

(*b*) When the tank unit float is all the way down, all of the rheostat resistance (25 ohms) is in terminal No. 2 circuit and none is in terminal No. 1 circuit. Most of the current will flow through terminal No. 1 circuit and the bimetal blade *A*. This current through the resistance wire on blade *A* will heat the blade making it deflect clockwise and push the indicator pointer to empty.

(*c*) When the tank unit float is raised all the way up, the rheostat resistance is zero in terminal No. 2 circuit and 25 ohms in terminal No. 1 circuit. The resistance wire around the bimetal blade *B* will then receive most of the current and become heated. Blade *B* deflects counterclockwise when heated so that it pushes the indicator pointer toward full.

(*d*) The outside bimetal blades *C* and *D* compensate for the effect of outside air temperature on blades *A* and *B* and also compensate for the variation in battery voltage. The combined deflection of the blades, due to the temperature reached when 5 volts is across the gage, opens the contact points *E*. Below 5 volts, the contact points do not open. Above 5 volts, they open and close intermittently to maintain constant input to the gage. The insulated contact points *F* merely act as an anchor for the entire operating mechanism for the purpose of temperature compensation.

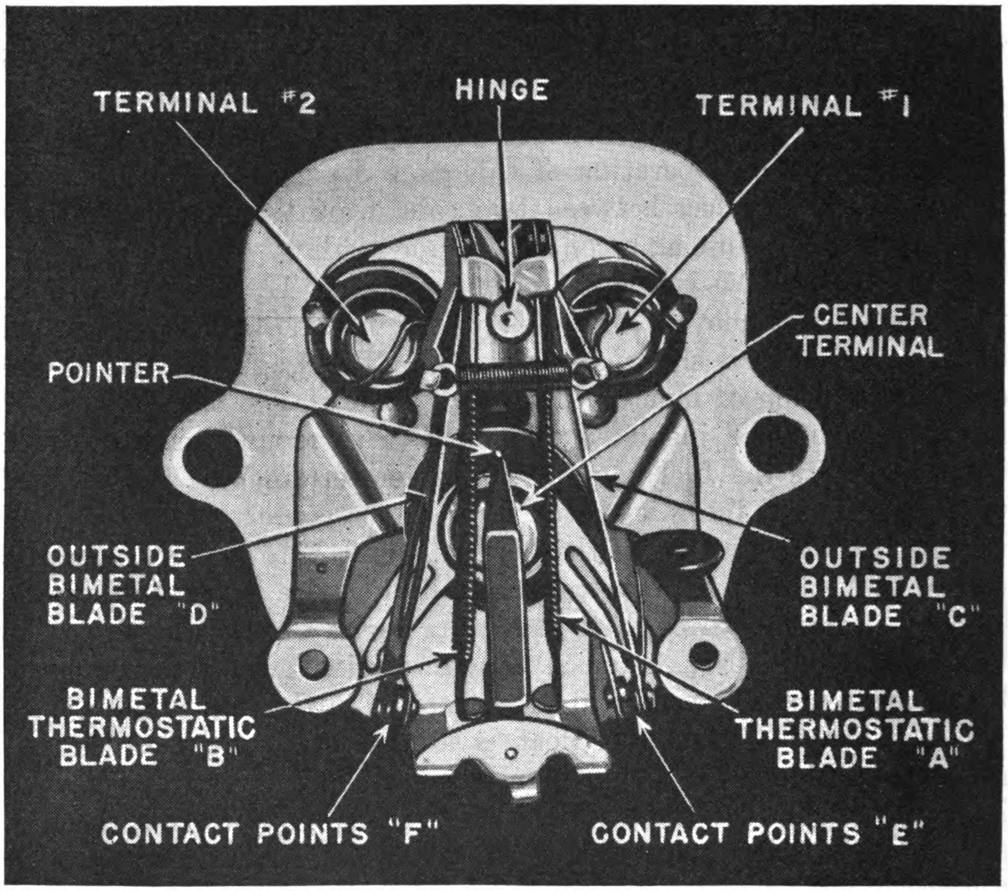
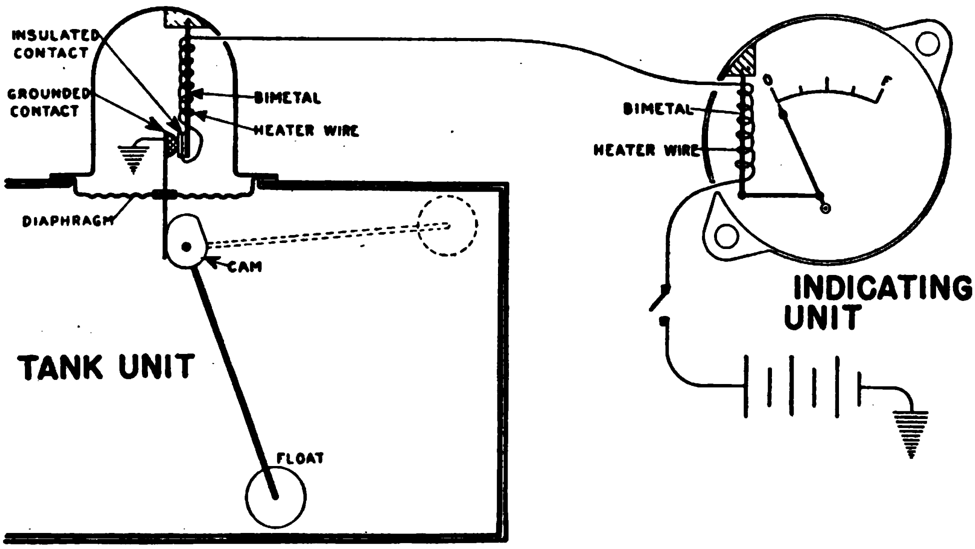


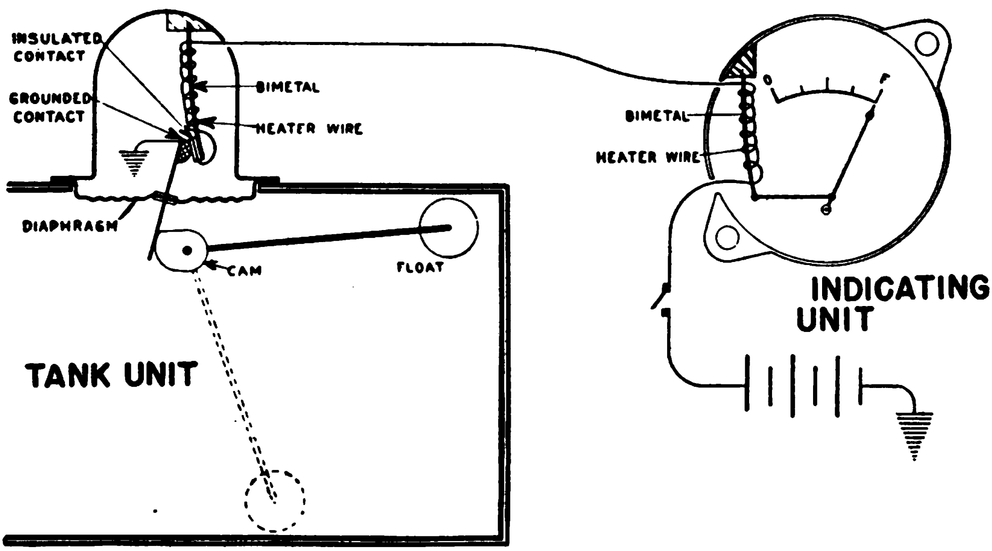

FIGURE 126.—Dash indicating unit of a bimetal thermostatic fuel gage (dial removed).

(3) *Thermostatic indicating unit and tank unit type.*—(*a*) Another type of thermostatic electric fuel gage has bimetal blades in both indicating and tank units. This type gage may also be used as a temperature or oil pressure gage by using changes in pressure or temperature to operate the movable grounded contact in the tank or sender unit.

(*b*) When the tank is empty and the float is down (fig. 127 ①), the two contacts in the tank unit are just touching. Current flows through the resistance heater wires of both indicating and tank units causing the bimetal blades to bend. Bending of the bimetal blade in the tank unit separates the contacts to break the circuit. The heater wire cools when the current stops flowing and the bimetal blades return to their original position. Contact is again made and the cycle of operation is repeated approximately every second. Opening




① Operation with tank empty.




② Operation with tank full.

FIGURE 127.—Fuel gage in which both indicating and tank units are thermostatically operated.

and closing of the contacts gives an intermittent flow of current which does not heat the indicating unit blade sufficiently to bend it. The blade then holds the pointer at the empty reading.

(*c*) When the tank is full, the action of the float and cam (fig. 127 ②), pushes the grounded contact against the insulated bimetal contact, bending the bimetal blade in the tank unit. Since the bimetal is then under a strain, the current must flow longer to bend it sufficiently to open the contacts. The longer flow of current will then cause a bending of the bimetal blade in the indicating unit and push the pointer over to the full position.

(*d*) The contacts open and close fast enough to give a steady reading by the pointer. The maximum current requirement for a full reading is less than ¼ ampere. This type of gage is not affected by variations of battery voltage and is compensated for outside air temperature variations.

**86. Turn indicators.**—*a*. Various electrical devices have been used on motor vehicles to indicate in which direction the driver intends to turn. An electric hand or arm that projects from the side of the vehicle is one device used. The present tendency is to have arrows on the front and back of the vehicle which are illuminated to indicate the direction of turn.

*b*. The electric arm is operated by a switch closing a circuit to an electromagnet which acts through a linkage to pull the arm outward. This turn indicator is used in Europe but very seldom in the United States.

*c*. A few manufacturers have provided a manually operated switch lever on the steering column to light the turn indicating arrows at the front and rear of the vehicle. Pilot lights on the instrument panel show when the turn indicator is operating and whether the right or left turn light is on. A flasher unit is sometimes included to make the proper front, rear, and pilot indicating lights flash on and off when the signal switch is turned on. After the turn has been made, the switch lever is automatically returned to "off" as the steering wheel is turned back to the straight ahead position.

**87. Horns.**—*a*. The most common type of horn is the vibrator type in which the general principle of operation is the same as that of a vibrating coil. A vibrating diaphragm is operated by the coil which also operates the contacts that break the circuit. Magnetism from the coil pulls the diaphragm toward it when the contacts are closed. The contacts are then pulled open by the coil, reducing the magnetism and allowing the diaphragm to return to its normal position. When the contacts are closed again, a new surge of current

induces magnetism in the coil and starts a second movement of the diaphragm. This cycle is repeated rapidly. The vibrations of the diaphragm within an air column produce the note of the horn.

*b.* Typical horn construction is shown in figure 128. Tone adjustment of the horn is made by loosening the adjusting lock nut and turning the adjusting nut until the proper tone is obtained. This very sensitive adjustment controls the current consumed by the horn. Increasing the current increases the volume. However, too much current will make the horn sputter and may lock the diaphragm.

*c.* In dual horns, one horn with a low pitch is blended with another horn with a high pitch. These horns, although operated electrically,

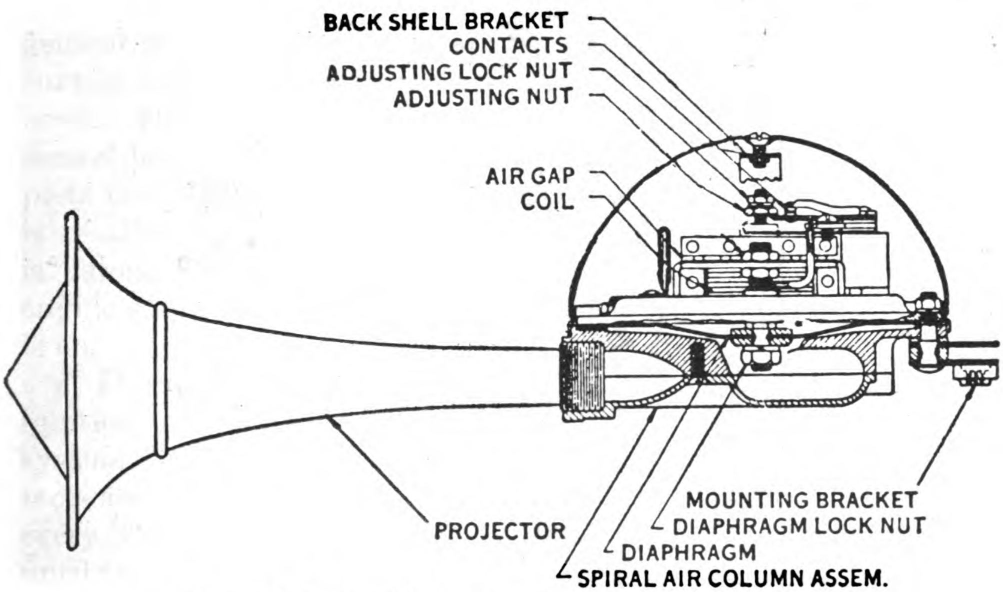



FIGURE 128.—Electric horn construction (vibrator type).

produce a sound closely resembling that of an air horn. The sound frequency of the low pitch horn is controlled by a long air column and that of the high pitch horn by a short air column. The air column is formed by the projector and by a spiral passage which is cast into the base of the horn.

*d.* Inasmuch as the total current required by a horn is approximately 12 amperes, dual horns are operated by a relay switch and controlled by the horn button. The relay, when adjusted properly, should close at 4 volts; therefore, when the voltage available is less than 4 volts, the horns will not operate.

**88. Startix automatic starting switch.**—*a.* The Startix is an automatic switch which controls the starting motor of an engine equipped with the Bendix starter drive. A starter button is not

needed. When the ignition key is turned to the "on" position, the Startix instantly and automatically operates the starting motor. If the engine stalls at any time while the ignition is on, the Startix automatically restarts the engine.

*b.* Inside the Startix unit are two solenoids with movable plungers held out by springs. The main solenoid has one coil winding and operates the starting motor circuit. The relay solenoid has two coil windings, one connected in the starting motor circuit and the other in the generator circuit (fig. 129). Both windings have a common ground but receive their current from different sources and are active at different times.

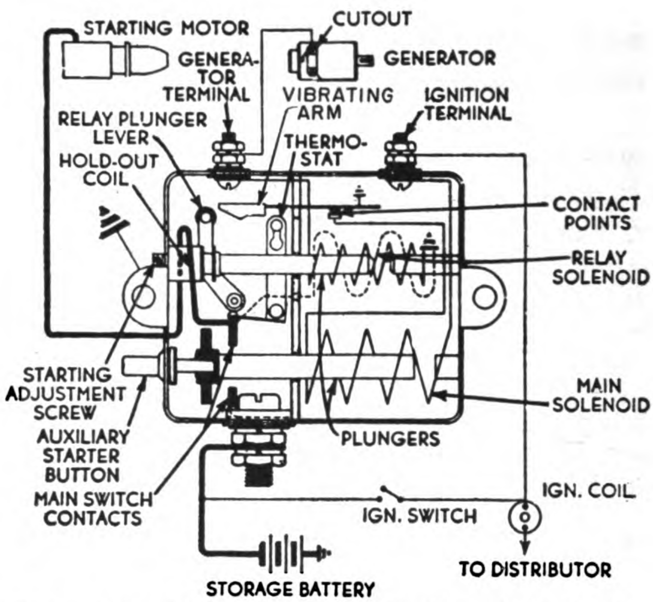



FIGURE 129.—Startix automatic starting switch circuit.

*c.* When the ignition key is on, electric current from the battery enters at the ignition terminal and passes through the main solenoid coil to two contact points, one stationary and the other, which is grounded, mounted on a vibrating arm. The current through the main solenoid pulls its plunger in to close the main switch contacts. This completes the circuit from the battery through to the starting motor, whereupon the Bendix pinion automatically meshes with the flywheel and cranks the engine until it starts. A large one-half turn hold-out coil is in series with this circuit to hold the relay solenoid plunger out while the engine is being cranked.

*d.* When the engine starts, the Bendix pinion is automatically disengaged from the flywheel. The current passing through the one-half turn hold-out coil is decreased and its effect on the plunger of

the relay solenoid is overbalanced by the outer starting motor circuit winding on the relay solenoid which pulls in the plunger. The inward travel of this plunger pulls the relay plunger lever over until it comes in contact with the vibrating arm and trips open the contact points to the main solenoid circuit. This releases the main solenoid plunger, opening the main switch contacts and breaking the starting motor circuit.

*e*. When the engine starts, current from the generator energizes the inner windings of the relay solenoid and holds the plunger in. Thus the starting motor switch contacts are open as long as the engine is running. The maximum current drain of this winding is only ½ ampere.

*f*. If the engine stops at any time while the ignition is on, the generator circuit winding of the relay solenoid loses its magnetizing current and releases the plunger, which in turn releases the plunger lever. The vibrating arm is then released and vibrates for about 1 second before it comes to rest to close the contact points which complete the circuit through the main solenoid. The delay of 1 second is to allow the engine to come to complete rest. The starting cycle is automatically repeated. Regardless of the number of times the engine stops, Startix automatically restarts it as long as the ignition is on.

*g*. If the starting motor stalls under a cranking load or if the ignition is unintentionally left on, a thermostat protects the starter system. This thermostat is connected to one of the main switch contacts and automatically opens the starting motor circuit momentarily every 30 to 60 seconds. The circuit is repeatedly opened and closed until the ignition is turned off. A distinctive clicking sound is caused by the thermostat contacts to warn the operator that the ignition should be turned off. An auxiliary starter button is provided on the side of the unit for cranking when the ignition is turned off or for cranking when making adjustments on the engine. This button can be used if the Startix fails to operate when the ignition is turned on. It should be pressed hard and released quickly.

**89. Accessories.**—*a*. Accessories such as electric windshield wipers, heaters, and fans depend upon small electric motors for their operation. These motors use about 45 watts. They should be connected to the ammeter so that any battery discharge required to run them is registered on the ammeter.

*b*. The electric windshield wiper has suitable gearing placed on the motor shaft to provide the reciprocating motion required to operate the wipers. Heaters and fans have fan blades mounted on the motor

shafts to circulate air within the car. The heater fan forces air through a heating element, similar to a radiator, which on most heaters is heated by the engine cooling water.

**90. Automotive radio.**—While the supply and maintenance of radio equipment is properly a responsibility of the Signal Corps, its use by motor vehicle units for coordinating convoy movements in isolated areas must often be considered. Transmitting and receiving equipment of this type depends upon the electrical system of the vehicle in which it is installed for its source of power.

*a. Installation.*—Installation of these units varies in different types and makes of equipment. In general, units of radio equipment should be mounted on brackets, panels, or metal members that are securely attached to the body or frame by welding or riveting. All paints, lacquers, or primers should be removed from all mounting surfaces coming in direct contact with the equipment and the surfaces tinned in order to insure the best possible ground. The units should be located so that all switches or controls are within easy access of the operator. All flexible control cables should be free of sharp bends. Insofar as possible, installation or removal of this type of equipment should be done by specialists of the Signal Corps trained in this type of work.

*b. Power requirements.*—Radio units require from 4 to 5 amperes for receivers and 12 to 16 amperes for large units and transmitters. In many instances, it will be found necessary to equip the vehicle with a larger generator with a regulator device to supply the additional current. All power leads from the vehicle electrical system should be of sufficient size to meet the current requirements and should be equipped with fuzes or other overload protective devices. All leads should be as short as possible. High voltage direct current is sometimes necessary, in which case a motor generator is required.

*c. Interference.*—(1) All sources of interference must be eliminated or controlled when radio receivers are installed in motor vehicles. Sources of interference are ignition, generator brushes, vibrating contacts in fuel gages, potential differences between loosely fitted metal panels, improperly grounded shielding, and other metal parts making intermittent contact.

(2) Interference may enter a completely shielded radio unit through the power source or it may be radiated and picked up by the antenna system. Most of the interference generated in a motor vehicle can be "blocked out" of the radio by filter circuits made of choke coils and bypass condensers. The manufacturers of modern radio apparatus have developed filter systems to the point where they will control most of the interference. Exceptional cases will be found, however, and

these must be corrected individually. Corrective measures include low impedance bonds from engine to frame, frame to body, or engine to body; high capacity condensers at source of interference; and shields for wiring that radiate or influence interference.

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[A. G. 062.11 (9–16–40).]

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